Appendix C

Reservoir Flood Operation

Many of the flood control features and options described in this appendix are illustrated with a single reservoir model (shown in Examples 1 and 2). Flood control operation may also apply to multi-reservoir systems. A four-reservoir system is used to explain options useful in flood control system operation (shown in Example 3).

To simulate the operation of a single flood control reservoir or a system of reservoirs operating to reduce downstream flooding, the basic components of the surface water system must first be defined. These include: streamflow data (including local inflow between control points), physical and operational characteristics of the reservoirs, and operational channel capacities for the reservoir and downstream control points in the system.

C.1 Single Reservoir Model

The first example is a single reservoir model which illustrates the default HEC-5 operation to reduce flooding at downstream locations.

C.1.1 Basic Reservoir Model Data

Figure C.1 shows a schematic of a single flood control reservoir (Reservoir 44) and a downstream control point (CP 40). The reservoir is operated to reduce flooding at CP 40. The basic reservoir storage data 1, are shown in Table C.1 and are further described in the following paragraphs. The data listing is shown in Table C.2.

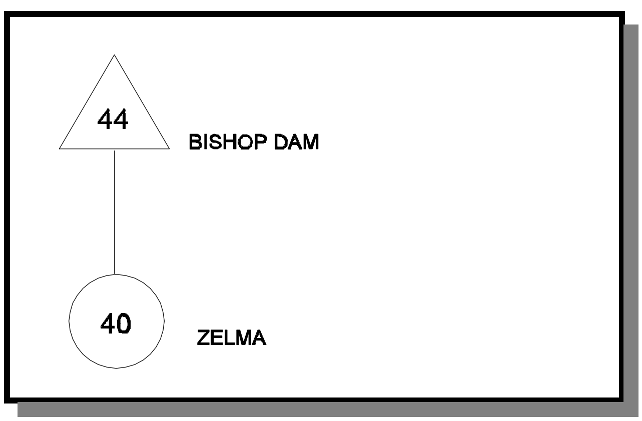

Figure C.1 Single Flood Control Reservoir
(Examples 1 and 2)

Table C.1 Reservoir Storage Levels, Volumes & Elevations (Example 1)

Storage Level Top of:	Level Number	Cumulative Storage (1000 m^3)	Elevation (meters)
Inactive Pool	1	131,438	250.2
Buffer Pool	2	134,000	250.4
Conservation	3	146,480	251.5
Flood Control	4	562,248	283.2
Dam	5	630,063	286.8

Reservoir Levels. In the first example (EXAMPLE1.DAT), five reservoir index levels (see **J1** Record, field 3) are defined at Reservoir 44. Table C.1 shows the cumulative storage for each of these index levels. The cumulative storage values are input on the **RL** record.

Reservoir Operation Criteria. The **RO** Record specifies the downstream control points that the reservoir operates for. A reservoir can operate for any or all of the locations that are dendritically located downstream. By default, each reservoir operates for itself. In Example 1, this means that the reservoir will operate to meet the minimum desired (80 m^3/s) and required (3 m^3/s) flows specified on the **CP** Record (fields 3 and 4) for Reservoir 44 while not exceeding its own channel capacity of 425 m^3/s (**CP** Record, field 2). In addition to itself, Reservoir 44 operates for one downstream location, Control Point 40, where the non-damaging channel capacity is specified as 450 m^3/s (**CP** Record, field 2).

R**eservoir Storage-Outflow-Elevation Data.** The reservoir's storage-outflow capacity are defined on the **RS** and **RQ** Records. The outflow data on the **RQ** Record should be the maximum outflow capability, which is an important constraint in flood operations. If the reservoir pool level rises above the top-of-flood control, the reservoir outflow will be based on the **RS-RQ** relation. This would represent operation of the emergency spillway. Below top-of-flood, the **RQ** data serves as the maximum value for the computation of reservoir releases. Therefore, release will be less than, or equal to the limiting capacity defined on the **RQ** Records.

The optional **RE** Record defines water surface elevation and is used in gated spillway and other options. Reservoir surface area is given on the **RA** Record and is used in computing evaporation, if given. Evaporation is not used in these flood operation examples.

Table C.2 Single Reservoir Input Data (Example 1)

```
T1      HEC-5 Example 1, Basic Flood Regulation   (EXAMPLE1.DAT)
T2      SI Units, 24 Hrs Foresight with 20% Contingency
T3      Rocky River, Bishop Dam Site to Zelma, 9-13 Nov 1973 Flood
J1     1       1       5       3       4       2
J2    24     1.2               0       0       0
J3     5                      -1               1
J8 44.09   44.10   44.12   44.13   40.04   40.02   40.24
JZ-44.10   44.13   44.22   40.04   40.02   40.17   44.09   44.24   40.24

C  ============== Bishop Dam Site =============
RL    44  146480  131438  134000  146480  562248  630063
RO     1      40
RS    13       0  124113  131438  134000  146480  253628  362008  417740  465211
RS546342  562248  589251  630063
RQ    13       0     333     665     668     681     796     872     912    2322
RQ  5664    6457    7646    9629
RE    13   209.7   249.6   250.2   250.4   251.5   262.1   270.5   274.3   277.4
RE 282.2   283.2   284.7   286.8
CP    44     425      80       3
IDBISHOP DAM
RT    44      40     1.2     0.3     3.0

C  =============== Zelma ===============
CP    40     450
IDZELMA
RT    40
ED

C    ------------------- Flood of Nov 9-13 1973 ----------------------------
BF     2      32              73110906               3
C    ----------- Local Flow at Bishop Dam Site -----------------------
IN    44
IN    67      78     159     215     309     473     605     704     960    1022
IN  1133    1378    1696    1787    2405    2616    2150    1974    1796    1660
IN  1396    1167     918     861     704     548     384     235     199     157
IN   226     197
C    ----------- Local Flow at Zelma -------------------------
IN    40
IN    52      62      78     197     231     289     473     460     509     608
IN   756     934    1036     882     715     529     374     326     217     106
IN    97      80      77      75      73      70      67      65      63      61
IN    59      57
ZW   A=EXAMPLE 1   F=BASIC FLOOD REGULATION
EJ
ER
```

Channel Capacity. The maximum channel capacity at the reservoir is used to control releases during flood operations. The channel capacity at Reservoir 44 is 425 m^3/s and is specified in the second field of the **CP** Record. Additionally, because Reservoir 44 operates for Control Point 40, the channel capacity of 450 m^3/s (**CP** Record, field 2 at Control Point 40) will also be considered when determining the reservoir releases.

Channel Routing. Seven channel routing methods are available in HEC-5. The routing sequence and the routing information are given on the **RT** Record. In this example, CP 44 routes water to CP 40 using one sub-reach with the Muskingum method (field 3). The Muskingum X is 0.3 and the travel time (K) for the sub-reach is 3 hours (**RT** Record, fields 4 and 5).

Streamflow. Inflows into the reservoir and incremental local flows into CP 40 are defined on **IN** Records. Each flow represents the average inflow for a three hour time interval (**BF** Record, field 7). The alternative to reading in flow values on **IN** Records would be to define a HEC-DSS file and use the **ZR** Record to equate the **IN** Records to pathnames in the HEC-DSS file. Example 2 will demonstrate reading flow data from an HEC-DSS file. The **ZW** Record, in conjunction with the **JZ** Record, is used for writing HEC-5 results to HEC-DSS.

The HEC-5 input for Example 1 is shown in Table C.2. For a detailed description of the input format and data requirements, see Appendix G, Input Description.

C.1.2 HEC-5 Results for Example 1

Example 1 is a single reservoir model where the reservoir operates to reduce flooding at a downstream location. A contingency factor of 20% (applied to local flows) and a 24-hour foresight (used in conjunction with the routing coefficients) are used in determining releases from the reservoir that would not contribute to flooding. Excerpts from the output file (EXAMPLE1.ANS) are shown in various tables and are discussed in detail using numbered references.

The routing coefficients resulting from using the Muskingum routing method in Example 1 (for the reach from Reservoir 44 to Control Point 40) are shown in Table C.3. For discussion purposes, let's assume that the reservoir release is being determined for the first period (9 Nov 73, 6:00-9:00 a.m.). Whatever release is made from reservoir 44 for period 1 ("current" period), then:

① 16.7% of period 1's release will reach CP 40 in period 1;
② 69.5% of period 1's release will reach CP 40 in period 2;
③ 11.6% of period 1's release will reach CP 40 in period 3;
④ 1.9% of period 1's release will reach CP 40 in period 4;
⑤ 0.3% of period 1's release will reach CP 40 in period 5.

Table C.3 Muskingum Method Routing Coefficients (Example 1)

```
*Routing/Operation Summary  (Coefficients Based on   3 Hours)


ROUTING COEFFICIENTS from Reservoir 44 to Downstream Location(s):
Loc=   40  0.1668  0.6949  0.1158  0.0193  0.0032
             ①       ②       ③       ④       ⑤
```

A summary of pertinent input data for Example 1 is shown in Table C.4. For flood control operation, the primary items of interest are the channel capacities and the flood control storage at the reservoir.

Table C.4 Summary of Pertinent Input Data (Example 1)

```
*Map 2

          HEC-5 Example 1, Basic Flood Regulation   (EXAMPLE1.DAT)


            Channel    Flood    Conserv.  Min Des.  Min Req. Divert   Map   Location
            Capacity  Storage   Storage     Flow      Flow     to    Number Name

44R BISHOP    425.    415768.    15042.      80.       3.      0      44    BISHOP
40  ZELMA     450.         0.        0.       0.       0.      0      40    ZELMA
```

Table C.5 is a User Designed Output table resulting from the **J8** Record input for Example 1. This table shows four major items of interest at Reservoir 44 and three items of interest at Control Point 40:

①	Inflow	-	Inflow into Reservoir 44;
②	Outflow	-	Release from Reservoir 44;
③	Case	-	The "reason" for making the reservoir release;
④	Level	-	An indication of how full the reservoir is; e.g., in this example, Level 3 is the Top-of-Conservation Pool;
⑤	Flow Reg	-	The regulated flow at the downstream location, CP 40;
⑥	Natural	-	The unregulated flow at the downstream location, CP 40;
⑦	Loc Incr	-	The Incremental Local Flow between Reservoir 44 and the downstream location CP 40.

Notice that Reservoir 44 begins the simulation (period 1) by operating for its own desired flow goal of 80 m^3/s (CP Record, field 3). Starting in period 2, the reservoir begins to cut back its release(to prevent flooding at location 40) but the Rate-of-change (CASE=0.02) limits the change in its release. This was due to the input Rate-of-Change (J2 Record, field 3) being set to the default value of .04 times the channel capacity at the reservoir (425 m^3/s) times 3 hours (simulation time interval) = 51 m^3/s. Therefore, since the release in period 1 is 80 m^3/s and the maximum change in release is 51 m^3/s (for a 3 hour time interval), then the release for period 2 is determined to be 29 m^3/s.

During periods 3 through 17, no reservoir release is made because any routed release would contribute to the flow at location 40, exceeding its channel capacity within the foresight of 24 hours (the number of hours of foresight was input on the J2 Record, field 1 as 24 hours). The CASE values indicate that the "reason" for the zero release is based on flooding at location 40 during future periods. In the third period for instance, the CASE is 40.04 which indicates forecast flooding at location 40 four periods in the future. In periods 18 through 24, the reservoir determines that there is space downstream for additional water and begins to evacuate the water stored in the flood pool (reservoir level is above Level 3). However, once again the release is limited by the Rate-of-Change constraint

(CASE=0.02) and the reservoir increases its releases in steps of 51 m^3/s until it determines that the forecasted flow at the downstream location will again exceed its channel capacity. At that time (period 25) the reservoir begins cutting back its release.

Table C.5 User Designed Output Table Resulting from J8 Record (Example 1)

```
*USERS. 1    User Designed Output    (Dates shown are for END-of-Period)
                                                Summary by Period   Flood=       1
```

				BISHOP DA	BISHOP DA	BISHOP DA	BISHOP DA	ZELMA	ZELMA	ZELMA
Location No=				44.	44.	44.	44.	40.	40.	40.
J8/JZ Codes=				44.090	44.100	44.120	44.130	40.040	40.020	40.240
Per	Date:	Hr	Day	Inflow	Outflow	Case	Level	Flow Reg	Natural	Loc Incr
1	9Nov73	9	Fri	67.00	80.00	0.00	2.99	132.00	119.00	52.00
2	9Nov73	12	Fri	78.00	29.00	0.02	3.00	133.50	130.83	62.00
3	9Nov73	15	Fri	159.00	0.00	40.04	3.01	109.25	167.97	78.00
4	9Nov73	18	Fri	215.00	0.00	40.03	3.01	202.21	353.83	197.00
5	9Nov73	21	Fri	309.00	0.00	40.04	3.02	231.87	451.97	231.00
6	9Nov73	24	Fri	473.00	0.00	40.04	3.03	289.15	610.66	289.00
7	10Nov73	3	Sat	605.00	0.00	40.04	3.05	473.03	942.78	473.00
8	10Nov73	6	Sat	704.00	0.00	40.04	3.06	460.01	1058.96	460.00
9	10Nov73	9	Sat	960.00	0.00	40.04	3.09	509.00	1238.16	509.00
10	10Nov73	12	Sat	1022.00	0.00	40.03	3.12	608.00	1539.86	608.00
11	10Nov73	15	Sat	1133.00	0.00	40.02	3.15	756.00	1781.48	756.00
12	10Nov73	18	Sat	1378.00	0.00	40.01	3.18	934.00	2089.91	934.00
13	10Nov73	21	Sat	1696.00	0.00	40.00	3.23	1036.00	2429.99	1036.00
14	10Nov73	24	Sat	1787.00	0.00	40.00	3.27	882.00	2542.83	882.00
15	11Nov73	3	Sun	2405.00	0.00	40.00	3.33	715.00	2583.97	715.00
16	11Nov73	6	Sun	2616.00	0.00	40.00	3.40	529.00	2879.83	529.00
17	11Nov73	9	Sun	2150.00	0.00	40.00	3.46	374.00	2868.14	374.00
18	11Nov73	12	Sun	1974.00	51.00	0.02	3.51	334.50	2504.02	326.00
19	11Nov73	15	Sun	1796.00	102.00	0.02	3.55	269.42	2195.34	217.00
20	11Nov73	18	Sun	1660.00	153.00	0.02	3.59	208.24	1909.72	106.00
21	11Nov73	21	Sun	1396.00	204.00	0.02	3.62	250.04	1736.95	97.00
22	11Nov73	24	Sun	1167.00	255.00	0.02	3.65	284.01	1478.49	80.00
23	12Nov73	3	Mon	918.00	306.00	0.02	3.66	332.00	1241.08	77.00
24	12Nov73	6	Mon	861.00	357.00	0.02	3.68	381.00	1024.51	75.00
25	12Nov73	9	Mon	704.00	378.92	40.01	3.68	425.15	922.59	73.00
26	12Nov73	12	Mon	548.00	328.16	40.00	3.69	436.00	772.26	70.00
27	12Nov73	15	Mon	384.00	379.16	0.02	3.69	409.97	613.38	67.00
... Periods 28-31 not shown ...										
32	13Nov73	6	Tue	197.00	346.89	40.00	3.67	438.60	269.81	57.00
			Sum =	30179.00	4469.73	880.53	108.10	13873.92	39723.82	9678.00
			Max =	2616.00	395.73	40.04	3.69	1036.00	2879.83	1036.00
			Min =	67.00	0.00	0.00	2.99	109.25	119.00	52.00
			PMax=	16.00	31.00	3.00	27.00	13.00	16.00	13.00
			Avg =	943.09	139.68	27.52	3.38	433.56	1241.37	302.44

In summary, the following can be concluded about the simulation results in Example 1:

① The maximum inflow to Reservoir 44 was 2616 m^3/s (period 16) and the maximum outflow was 396 m^3/s (period 31).

② The channel capacity of 450 m^3/s at the downstream location (Location 40) was exceeded due to its uncontrolled local flow (not due to releases from Reservoir 44).

③ Without the operation of Reservoir 44, the maximum flow at Location 40 would have peaked at 2880 m^3/s (during period 16). With the operation of Reservoir 44, the peak flow at Location 40 was reduced to 1036 m^3/s (during period 13).

Since it may be useful to see the results of an HEC-5 simulation displayed in graphical form and/or perform statistical or mathematical operations on the results, then the option of storing data to HEC-DSS may be used. Table C.6 shows the JZ and ZW Records that were used in Example 1 to specify which results (JZ Record) and which pathnames (ZW Record) are to be written to HEC-DSS.

Table C.6 Storing HEC-5 Simulation Results to HEC-DSS (Example 1)

```
JZ-44.10   44.13   44.22   40.04   40.02   40.17   44.09   44.24   40.24

ZW   A=EXAMPLE 1   F=BASIC FLOOD REGULATION


   -----DSS---ZOPEN:  New File Opened,  File: EXAMPLE1.DSS
                      Unit:  72;  DSS Version: 6-JE

    ----- Flood Number  1 -----

---DSS---ZWRITE Unit 72; Vers. 1:/EXAMPLE 1/BISHOP DAM/FLOW-RES OUT/01NOV1973/3HOUR/BASIC FLOOD REGULATION/
---DSS---ZWRITE Unit 72; Vers. 1:/EXAMPLE 1/BISHOP DAM/LEVEL-RES/01NOV1973/3HOUR/BASIC FLOOD REGULATION/
---DSS---ZWRITE Unit 72; Vers. 1:/EXAMPLE 1/BISHOP DAM/ELEV/01NOV1973/3HOUR/BASIC FLOOD REGULATION/
---DSS---ZWRITE Unit 72; Vers. 1:/EXAMPLE 1/ZELMA/FLOW-REG/01NOV1973/3HOUR/BASIC FLOOD REGULATION/
---DSS---ZWRITE Unit 72; Vers. 1:/EXAMPLE 1/ZELMA/FLOW-NAT/01NOV1973/3HOUR/BASIC FLOOD REGULATION/
---DSS---ZWRITE Unit 72; Vers. 1:/EXAMPLE 1/ZELMA/FLOW-CHAN CAP/01NOV1973/3HOUR/BASIC FLOOD REGULATION/
---DSS---ZWRITE Unit 72; Vers. 1:/EXAMPLE 1/BISHOP DAM/FLOW-RES IN/01NOV1973/3HOUR/BASIC FLOOD REGULATION/
---DSS---ZWRITE Unit 72; Vers. 1:/EXAMPLE 1/BISHOP DAM/FLOW-LOC INC/01NOV1973/3HOUR/BASIC FLOOD REGULATION/
---DSS---ZWRITE Unit 72; Vers. 1:/EXAMPLE 1/ZELMA/FLOW-LOC INC/01NOV1973/3HOUR/BASIC FLOOD REGULATION/

----- OUTPUT Data Written to DSS -----

   -----DSS---ZCLOSE Unit:  72,   File: EXAMPLE1.DSS
              Pointer Utilization:  0.25
              Number of Records:      9
              File Size:     21.8  Kbytes
              Percent Inactive:   0.0
```

C.1.3 Single Reservoir with Gated Spillway

The capability to simulate the regulation of large floods with "gate regulation curves" is an important HEC-5 flood regulation option. A typical application for this feature would be the routing of the spillway design flood or large historic flood which is larger than the flood storage design flood. The data required to define the induced storage zone, physical characteristics of the gated spillway and operation criteria are input on the **RG** Record. Example 2 demonstrates the regulation of a large flood with the gate regulation curve procedure. The input data for Example 2 (Table C.7) is basically the same as in Example 1, except for the following four items:

Table C.7 HEC-5 Input for Single Reservoir Gate Regulation (Example 2)

```
T1       HEC-5 Example 2, Gated Spillway Simulation (EXAMPLE2.DAT)
T2       Low Flow Release During Flooding, Rate of Change Constraints
T3       Rocky River, Bishop Dam Site to Zelma, 20-28 Dec 1964 Flood
J1      1       1       5       3       4       2
J2     24     1.2               8       0       0
J3      5                      -1               1
J8 44.09   44.10   44.36   44.12   44.13   44.22   40.04   40.02   40.24   40.19
JZ-44.10   44.36   44.13   44.22   40.04   40.02   40.17

C  ============== Bishop Dam Site =============
RL     44  146480  131438  134000  146480  562248  630063
RO      1      40
RS     13       0  124113  131438  134000  146480  253628  362008  417740  465211
RS546342  562248  589251  630063
RQ     13       0     333     665     668     681     796     872     912    2322
RQ  5664    6457    7646    9629
RE     13   209.7   249.6   250.2   250.4   251.5   262.1   270.5   274.3   277.4
RE 282.2   283.2   284.7   286.8
R2     70     225
RG 284.7   283.2     425    28.6    64.8   270.5      90     872     3.0   282.5
CP     44     425      80       3
IDBISHOP DAM
RT     44      40     1.2     0.3     3.0

C  ============== Zelma ===============
CP     40     450
IDZELMA
RT     40
ED

C    ------------------- Flood of Dec 20-28 1964 ---------------------------
BF      2      72       0        64122000       0       3                   1900
ZR   A=EXAMPLE 2  C=FLOW-LOC INC  F=MAXIMUM HISTORIC FLOOD
ZR=IN44  B=BISHOP DAM
ZR=IN40  B=ZELMA
ZW   A=EXAMPLE 2     F=GATED SPILLWAY SIMULATION
EJ
```

① A **RG** Record has been added to the reservoir data to indicate a gate regulation operation. Also, **J8**/**JZ** Records were revised to contain output code 44.36 which will tabulate gate regulation discharges.

② A priority has been input that specifies that low-flow releases will be made eventhough they may contribute to flooding (**J2** Record, field 4 = 8).

③ Rising and falling rate-of-change constraints have been specified at the reservoir (**R2** Record, fields 1 and 2).

④ Time Series Data: a historic flood similar to the spillway design flood event is used; flow values are read from HEC-DSS (see **ZR** Records); and, the Century of 1900 is input on the **BF** Record, Field 10.

C.1.4 Gate Regulation Results

The results of Example 2 (using the **RG** Record to invoke the Gate Regulation Operation), can best be illustrated by comparing the results with the Example 1 model (without the **RG** Record). The Example 1 model is referred to as a Method A operation, while the model with the **RG** Record is referred to as a Gated Spillway operation. Figure C.2 shows the Reservoir releases (at Bishop Dam) from the two models and Figure C.3 shows the downstream regulated flow (at Zelma) from the two models. For detailed discussion, excerpts from the HEC-5 output files are shown in Tables C.8 thru C.11. The following observations can be made from reviewing these figures and tables:

① In Figure C.2, the Method A operation (without the RG Record) indicates that the reservoir delays its release (to reduce downstream flooding) until the reservoir fills to the top-of-flood pool. At that time, releases equal to the inflow are made (unless the capacity of the release facilities is exceeded). The Gated Spillway operation shows that the reservoir begins releasing the flood flows earlier; the maximum release is reduced approximately 40 percent (from 1900 m^3/s to 1160 m^3/s); and, the maximum release occurs later in time.

② In Figure C.3, the maximum downstream regulated flow was reduced approximately 35 percent (from 2430 m^3/s to 1560 m^3/s) by using a Gated Spillway operation.

③ Table C.8 and Table C.9 show for each type of operation a Summary of Maximums (at the Bishop Dam reservoir and at the downstream channel control point location Zelma). Comparison of these tables shows that during the Gated Spillway operation (Table C.9), the Bishop Dam reservoir stored water in the surcharge pool (maximum HEC-5 level = 4.169, where the top-of-flood pool is level 4.0). However, during the Method A operation (Table C.8), water was not stored above the top-of-the flood pool (a surcharge pool was not defined). By storing water above the top-of-flood pool and making earlier releases, the maximum release was reduced and consequently the maximum downstream regulated flow was reduced by using the Gated Spillway operation.

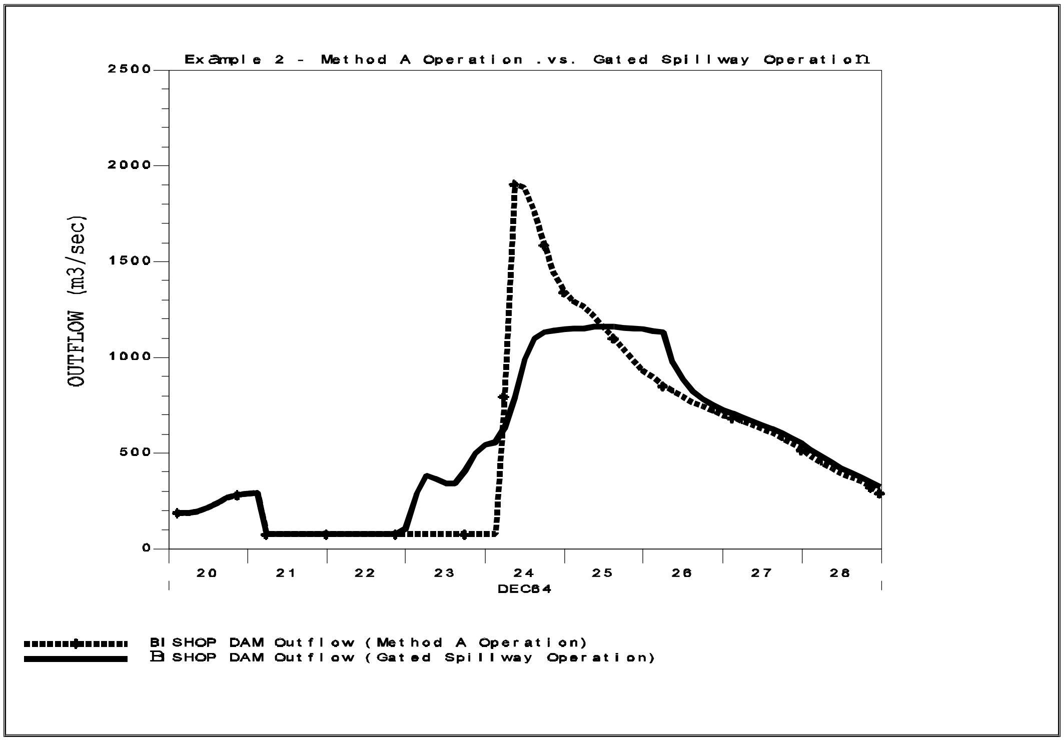

Figure C.2 Bishop Dam: With and Without Gate Regulation (Example 2)

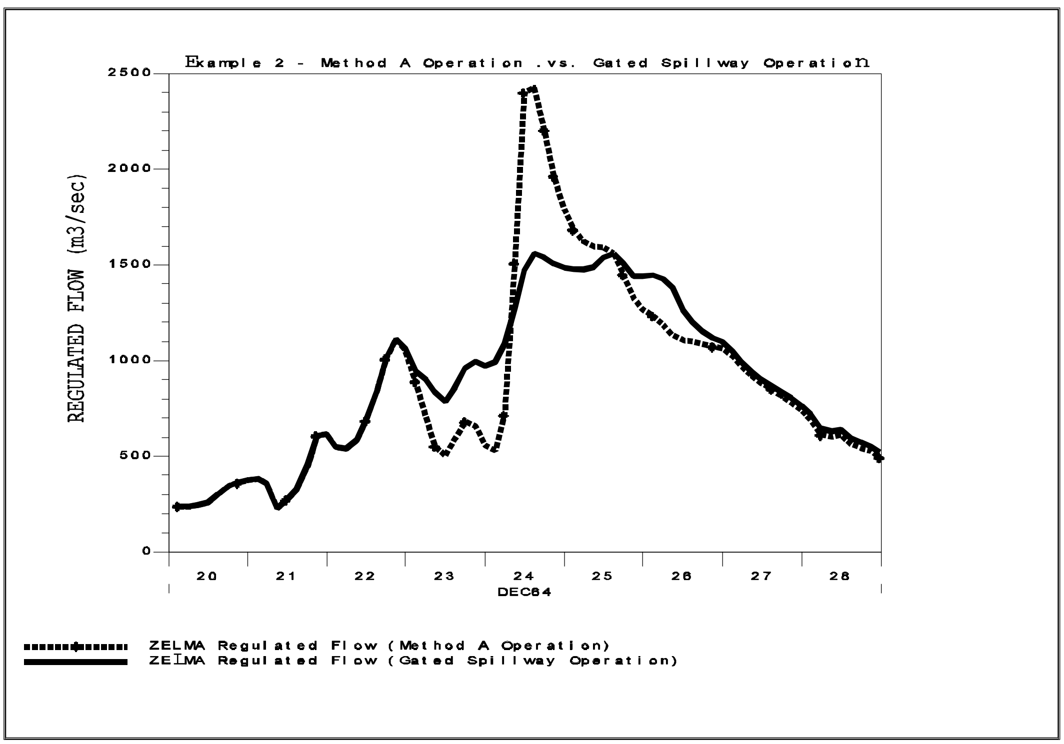

Figure C.3 Zelma: With and Without Gate Regulation (Example 2)

④ Table C.10 is a User Designed Output table resulting from the **J8** Record for the Method A operation (without **RG** Record). The pertinent reservoir operation information is shown in the first four columns: the inflow to Bishop Dam (Inflow); the release from Bishop Dam (Outflow); the HEC-5 "reason" for the release (Case); and, the HEC-5 level number (Level). By looking at these columns, it can be seen that the reservoir starts with a full conservation pool (Level 3) and releases inflow through time period 9. At that time, it is determined that the flow at the downstream location, Zelma, will exceed its channel capacity of 450 m^3/s (**CP** Record, field 2) within the forecast time of 24 hours (**J2** Record, field 1). Therefore, HEC-5 determines that the reservoir releases should be cut back. However, due to the input priority (**J2** Record, field 4), the reservoir releases the minimum flow of 80 m^3/s (even though flooding is occurring) during periods 10 through 33. The default Method A operation will cause the program to store water until flood storage is completely filled. When flood storage is exhausted, HEC-5 will make emergency releases (Case = 0.04) up to the capacity of the discharge facilities. In period 34 the reservoir releases 801 m^3/s and for the remainder of the simulation, the reservoir continues to release inflow and remains at the top-of-flood pool.

⑤ Table C.11 is a User Designed Output table resulting from the **J8** Record for the Gated Spillway operation (with **RG** Record). The pertinent reservoir operation information is shown as it was Table C.10 except an additional column has been included to show the releases determined during the Gate Regulation operation (Q-Gate R). By comparing these results with the results in Table C.10, it can be seen that the operations are exactly the same through period 23. At that time, the Gate Regulation criteria becomes the controlling factor and the reservoir releases are determined based on the **RG** Record input.

Table C.8 Summary of Maximums (Method A Operation: without RG Record)

```
                                              --------------
                  Summary of Maximums for    RESERVOIRS
                             --------        --------------

       HEC-5 Example 2, METHOD A Operation (WITHOUT Gated Spillway)
       Low Flow Release During Flooding, Rate of Change Constraints
       Rocky River, Bishop Dam Site to Zelma, 20-28 Dec 1964 Flood

            -------------------------------------------------------
            Period of Analysis:  STARTING :  20DEC64 - 0000 Hrs
                                 ENDING   :  28DEC64 - 2400 Hrs
                                 DURATION :  9 Days,  0 Hrs,  0 Min

                 Time Interval:    3 Hours,  0 Minutes
            -------------------------------------------------------

******************************************************************************
*    Reservoir    *     Max    *     Max    *    Max            *     Max    *
*                 *   Inflow   *   Outflow  *  Storage    Elev  *    HEC-5   *
*  ID    Name     *   (m3/s)   *   (m3/s)   * (1000m3)  (Meters)*    Levels  *
*                 *            *            *                   *            *
******************************************************************************
*                 *            *            *                   *            *
*  44 BISHOP DAM  *       3087 *       1912 *   562248   283.20 *      4.000 *
*                 * 22DEC-2400 * 24DEC-0900 *    24DEC-0600     * 24DEC-0600 *
*                 *            *            *                   *            *
******************************************************************************

            Maximum System Storage Used =   562248.  (24DEC-0600)

                                  -----------------------------------
          Summary of Maximums for    CHANNEL CONTROL POINT LOCATIONS
                     --------      -----------------------------------

       HEC-5 Example 2, METHOD A Operation (WITHOUT Gated Spillway)
       Low Flow Release During Flooding, Rate of Change Constraints
       Rocky River, Bishop Dam Site to Zelma, 20-28 Dec 1964 Flood

            -------------------------------------------------------
            Period of Analysis:  STARTING :  20DEC64 - 0000 Hrs
                                 ENDING   :  28DEC64 - 2400 Hrs
                                 DURATION :  9 Days,  0 Hrs,  0 Min

                 Time Interval:    3 Hours,  0 Minutes
            -------------------------------------------------------

******************************************************************************
*  Channel Location  *  Channel     Max     Q from *  Max Cum.  *    Max     *
*                    * Capacity  Reg. Flow    Res. *  Local Q   * Natural Q  *
*  ID    Name        *  (m3/s)    (m3/s)    (m3/s) *  (m3/s)    *  (m3/s)    *
******************************************************************************
*                    *                             *            *            *
*  44 BISHOP DAM     *     425       1912        0 *     3087   *      3087  *
*                    *           24DEC-0900        * 22DEC-2400 * 22DEC-2400 *
*                    *                             *            *            *
*  40 ZELMA          *     450       2430     1394 *     1036   *      3852  *
*                    *           24DEC-1500        * 22DEC-2100 * 23DEC-0300 *
*                    *                             *            *            *
******************************************************************************
```

Table C.9 Summary of Maximums (Gated Spillway Operation with RG Record)

```
                                              --------------
                  Summary of Maximums for    RESERVOIRS
                                --------      --------------

      HEC-5 Example 2, Gated Spillway Simulation (EXAMPLE2.DAT)
      Low Flow Release During Flooding, Rate of Change Constraints
      Rocky River, Bishop Dam Site to Zelma, 20-28 Dec 1964 Flood

           -------------------------------------------------------
           Period of Analysis:  STARTING :  20DEC64 - 0000 Hrs
                                ENDING   :  28DEC64 - 2400 Hrs
                                DURATION :  9 Days,  0 Hrs,  0 Min

                Time Interval:    3 Hours,  0 Minutes
           -------------------------------------------------------

*******************************************************************************
*    Reservoir    *     Max    *     Max    *    Max             *     Max    *
*                 *   Inflow   *   Outflow  *  Storage    Elev   *    HEC-5   *
*  ID    Name     *   (m3/s)   *   (m3/s)   * (1000m3)  (Meters)*    Levels  *
*                 *            *            *                    *            *
*******************************************************************************
*                 *            *            *                    *            *
*  44 BISHOP DAM  *       3087 *       1164 *   573676   283.83 *      4.169 *
*                 * 22DEC-2400 * 25DEC-0900 *    25DEC-0900      * 25DEC-0900 *
*                 *            *            *                    *            *
*******************************************************************************

           Maximum System Storage Used =   573676.  (25DEC-0900)

                                     -----------------------------------
         Summary of Maximums for    CHANNEL CONTROL POINT LOCATIONS
                     --------        -----------------------------------

      HEC-5 Example 2, Gated Spillway Simulation (EXAMPLE2.DAT)
      Low Flow Release During Flooding, Rate of Change Constraints
      Rocky River, Bishop Dam Site to Zelma, 20-28 Dec 1964 Flood

           -------------------------------------------------------
           Period of Analysis:  STARTING :  20DEC64 - 0000 Hrs
                                ENDING   :  28DEC64 - 2400 Hrs
                                DURATION :  9 Days,  0 Hrs,  0 Min

                Time Interval:    3 Hours,  0 Minutes
           -------------------------------------------------------

*******************************************************************************
*  Channel Location  *  Channel     Max     Q from *  Max Cum.  *    Max     *
*                    * Capacity  Reg. Flow    Res. *  Local Q   * Natural Q  *
*  ID    Name        *  (m3/s)    (m3/s)    (m3/s) *  (m3/s)    *  (m3/s)    *
*******************************************************************************
*                    *                             *            *            *
*  44 BISHOP DAM     *     425       1164        0 *     3087   *     3087   *
*                    *          25DEC-0900         * 22DEC-2400 * 22DEC-2400 *
*                    *                             *            *            *
*  40 ZELMA          *     450       1563      526 *     1036   *     3852   *
*                    *          25DEC-1500         * 22DEC-2100 * 23DEC-0300 *
*                    *                             *            *            *
*******************************************************************************
```

Table C.10 HEC-5 User Designed Output Table for Method A Operation (Example 2 without **RG** Record)

*USERS. 1   User Designed Output   (Dates shown are for END-of-Period)

Summary by Period   Flood=   1

Location No=				44.	44.	44.	44.	44.	40.	40.	40.	40.
J8/JZ Codes=				44.090	44.100	44.120	44.130	44.220	40.040	40.020	40.240	40.190
				BISHOP DA	BISHOP DA	BISHOP DA	BISHOP DA	BISHOP DA	ZELMA	ZELMA	ZELMA	ZELMA
Per	Date:	Hr	Day	Inflow	Outflow	Case	Level	EOP Elev	Flow Reg	Natural	Loc Incr	Q by US
1	20Dec64	3	Sun	192.58	192.58	0.03	3.00	251.50	241.85	241.85	49.27	192.58
2	20Dec64	6	Sun	192.58	192.58	0.03	3.00	251.50	241.85	241.85	49.27	192.58
3	20Dec64	9	Sun	198.24	198.24	0.03	3.00	251.50	247.09	247.09	53.57	193.52
4	20Dec64	12	Sun	216.64	216.64	0.03	3.00	251.50	263.09	263.09	62.57	200.52
5	20Dec64	15	Sun	242.14	242.14	0.03	3.00	251.50	306.84	306.84	88.64	218.20
6	20Dec64	18	Sun	271.87	271.87	0.03	3.00	251.50	345.51	345.51	102.40	243.11
7	20Dec64	21	Sun	286.03	286.03	0.03	3.00	251.50	363.92	363.92	94.48	269.44
8	20Dec64	24	Sun	290.28	290.28	0.03	3.00	251.50	378.07	378.07	94.10	283.97
9	21Dec64	3	Mon	297.36	297.36	0.03	3.00	251.50	385.16	385.16	94.75	290.41
10	21Dec64	6	Mon	297.36	80.00	0.00	3.01	251.73	361.67	397.90	101.70	259.97
11	21Dec64	9	Mon	297.36	80.00	0.00	3.01	251.96	231.97	419.14	121.97	110.00
12	21Dec64	12	Mon	417.72	80.00	0.00	3.02	252.33	277.37	509.76	192.37	85.00
13	21Dec64	15	Mon	559.32	80.00	0.00	3.03	252.84	328.83	672.60	248.00	80.83
14	21Dec64	18	Mon	715.08	80.00	0.00	3.05	253.52	447.63	930.32	367.49	80.14
15	21Dec64	21	Mon	909.07	80.00	0.00	3.07	254.40	611.14	1253.16	531.12	80.02
16	21Dec64	24	Mon	972.79	80.00	0.00	3.09	255.36	618.81	1427.33	538.81	80.00
17	22Dec64	3	Tue	1005.36	80.00	0.00	3.12	256.34	553.07	1437.24	473.07	80.00
18	22Dec64	6	Tue	1104.48	80.00	0.00	3.14	257.44	540.46	1475.48	460.46	80.00
19	22Dec64	9	Tue	1260.24	80.00	0.00	3.18	258.70	588.63	1624.16	508.63	80.00
20	22Dec64	12	Tue	1522.20	80.00	0.00	3.21	260.24	687.75	1887.53	607.75	80.00
21	22Dec64	15	Tue	1932.84	80.00	0.00	3.26	262.19	836.43	2306.67	756.43	80.00
22	22Dec64	18	Tue	2478.00	80.00	0.00	3.32	264.20	1014.37	2894.30	934.37	80.00
23	22Dec64	21	Tue	2895.72	80.00	0.00	3.40	266.56	1116.24	3497.52	1036.24	80.00
24	22Dec64	24	Tue	3086.88	80.00	0.00	3.47	269.08	1062.19	3837.36	982.19	80.00
25	23Dec64	3	Wed	3016.08	80.00	0.00	3.55	271.41	895.06	3851.52	815.06	80.00
26	23Dec64	6	Wed	2704.56	80.00	0.00	3.62	273.34	709.08	3596.64	629.08	80.00
27	23Dec64	9	Wed	2400.12	80.00	0.00	3.68	275.02	554.19	3171.84	474.19	80.00
28	23Dec64	12	Wed	2173.56	80.00	0.00	3.73	276.49	505.72	2837.67	425.72	80.00
29	23Dec64	15	Wed	2095.68	80.00	0.00	3.79	277.87	596.99	2717.30	516.99	80.00
30	23Dec64	18	Wed	2060.28	80.00	0.00	3.84	279.13	685.84	2713.06	605.84	80.00
31	23Dec64	21	Wed	1947.00	80.00	0.00	3.89	280.33	657.46	2626.68	577.46	80.00
32	23Dec64	24	Wed	1791.24	80.00	0.00	3.93	281.42	560.45	2418.53	480.45	80.00
33	24Dec64	3	Thu	1748.76	80.00	0.00	3.97	282.50	534.14	2262.77	454.14	80.00
34	24Dec64	6	Thu	1826.64	801.30	0.04	4.00	283.20	716.76	2288.26	516.54	200.22
35	24Dec64	9	Thu	1911.60	1911.60	0.04	4.00	283.20	1512.70	2458.18	626.53	886.17
36	24Dec64	12	Thu	1890.36	1890.36	0.04	4.00	283.20	2406.80	2564.37	669.64	1737.16
37	24Dec64	15	Thu	1762.92	1762.92	0.04	4.00	283.20	2430.50	2456.76	586.91	1843.59

Table C.10 HEC-5 User Designed Output Table for Method A Operation (without **RG** Record, continued)

Location No=				44.	44.	44.	44.	44.	40.	40.	40.	40.
				BISHOP DA	BISHOP DA	BISHOP DA	BISHOP DA	BISHOP DA	ZELMA	ZELMA	ZELMA	ZELMA
Per	Date:	Hr	Day	Inflow	Outflow	Case	Level	EOP Elev	Flow Reg	Natural	Loc Incr	Q by US
38	24Dec64	18	Thu	1593.00	1593.00	0.04	4.00	283.20	2207.41	2211.79	459.37	1748.04
39	24Dec64	21	Thu	1437.24	1437.24	0.04	4.00	283.20	1970.34	1971.07	377.46	1592.88
40	24Dec64	24	Thu	1345.20	1345.20	0.04	4.00	283.20	1793.95	1794.07	346.11	1447.84
41	25Dec64	3	Fri	1295.64	1295.64	0.04	4.00	283.20	1689.27	1689.29	335.22	1354.05
42	25Dec64	6	Fri	1267.32	1267.32	0.04	4.00	283.20	1625.56	1625.57	324.91	1300.65
43	25Dec64	9	Fri	1217.76	1217.76	0.04	4.00	283.20	1600.08	1600.08	335.46	1264.62
44	25Dec64	12	Fri	1161.12	1161.12	0.04	4.00	283.20	1594.42	1594.42	378.29	1216.13
45	25Dec64	15	Fri	1104.48	1104.48	0.04	4.00	283.20	1560.43	1560.43	399.58	1160.85
46	25Dec64	18	Fri	1047.84	1047.84	0.04	4.00	283.20	1454.23	1454.23	349.80	1104.43
47	25Dec64	21	Fri	984.12	984.12	0.04	4.00	283.20	1332.45	1332.45	285.80	1046.65
48	25Dec64	24	Fri	934.56	934.56	0.04	4.00	283.20	1274.40	1274.40	288.12	986.28
49	26Dec64	3	Sat	899.16	899.16	0.04	4.00	283.20	1237.58	1237.58	300.30	937.28
50	26Dec64	6	Sat	856.68	856.68	0.04	4.00	283.20	1186.61	1186.61	288.18	898.43
51	26Dec64	9	Sat	825.53	825.53	0.04	4.00	283.20	1134.22	1134.22	275.77	858.45
52	26Dec64	12	Sat	797.21	797.21	0.04	4.00	283.20	1108.73	1108.73	282.43	826.30
53	26Dec64	15	Sat	767.47	767.47	0.04	4.00	283.20	1105.89	1105.89	308.79	797.10
54	26Dec64	18	Sat	746.23	746.23	0.04	4.00	283.20	1090.32	1090.32	321.45	768.87
55	26Dec64	21	Sat	722.16	722.16	0.04	4.00	283.20	1077.57	1077.57	331.58	745.99
56	26Dec64	24	Sat	700.92	700.92	0.04	4.00	283.20	1067.66	1067.66	345.07	722.59
57	27Dec64	3	Sun	686.76	686.76	0.04	4.00	283.20	1025.18	1025.18	323.01	702.17
58	27Dec64	6	Sun	666.93	666.93	0.04	4.00	283.20	971.37	971.37	285.35	686.02
59	27Dec64	9	Sun	647.11	647.11	0.04	4.00	283.20	923.23	923.23	256.42	666.81
60	27Dec64	12	Sun	631.54	631.54	0.04	4.00	283.20	886.42	886.42	238.62	647.80
61	27Dec64	15	Sun	608.88	608.88	0.04	4.00	283.20	853.85	853.85	223.38	630.47
62	27Dec64	18	Sun	580.56	580.56	0.04	4.00	283.20	817.03	817.03	209.27	607.76
63	27Dec64	21	Sun	552.24	552.24	0.04	4.00	283.20	780.21	780.21	199.84	580.37
64	27Dec64	24	Sun	522.51	522.51	0.04	4.00	283.20	740.57	740.57	188.60	551.97
65	28Dec64	3	Mon	487.10	487.10	0.04	4.00	283.20	695.26	695.26	173.74	521.52
66	28Dec64	6	Mon	453.12	453.12	0.04	4.00	283.20	615.95	615.95	128.78	487.17
67	28Dec64	9	Mon	424.80	424.80	0.04	4.00	283.20	604.64	604.64	150.56	454.08
68	28Dec64	12	Mon	396.48	396.48	0.04	4.00	283.20	614.55	614.55	189.59	424.96
69	28Dec64	15	Mon	375.24	375.24	0.04	4.00	283.20	564.99	564.99	167.30	397.69
70	28Dec64	18	Mon	354.00	354.00	0.04	4.00	283.20	547.99	547.99	172.55	375.44
71	28Dec64	21	Mon	325.68	325.68	0.04	4.00	283.20	529.58	529.58	176.73	352.85
72	28Dec64	24	Mon	297.36	297.36	0.04	4.00	283.20	498.43	498.43	172.94	325.49
			Sum =	76684.89	38187.85	1.83	264.38	19672.70	63596.00	102093.05	25518.57	38077.43
			Max =	3086.88	1911.60	0.04	4.00	283.20	2430.50	3851.52	1036.24	1843.59
			Min =	192.58	80.00	0.00	3.00	251.50	231.97	241.85	49.27	80.00
			PMax=	24.00	35.00	34.00	34.00	34.00	37.00	25.00	23.00	37.00
			Avg =	1065.07	530.39	0.03	3.67	273.23	883.28	1417.96	354.42	528.85
			PMin=	1.00	10.00	10.00	1.00	1.00	11.00	1.00	1.00	16.00

Table C.11 HEC-5 User Designed Output Table for Gated Spillway Operation (Example 2 with **RG** Record)

```
 *USERS. 1    User Designed Output    (Dates shown are for END-of-Period)

                                                Summary by Period   Flood=       1
 Location No=             44.        44.        44.        44.        44.        44.        40.        40.        40.        40.
 J8/JZ Codes=             44.090     44.100     44.360     44.120     44.130     44.220     40.040     40.020     40.240
40.190

                       BISHOP DA  BISHOP DA  BISHOP DA  BISHOP DA  BISHOP DA  BISHOP DA  ZELMA      ZELMA      ZELMA      ZELMA
  Per  Date:  Hr Day    Inflow     Outflow    Q-Gate R   Case       Level      EOP Elev   Flow Reg   Natural    Loc Incr   Q by US

    1 20Dec64  3 Sun     192.58     192.58       0.00       0.03       3.00     251.50     241.85     241.85      49.27     192.58
    2 20Dec64  6 Sun     192.58     192.58       0.00       0.03       3.00     251.50     241.85     241.85      49.27     192.58
    3 20Dec64  9 Sun     198.24     198.24       0.00       0.03       3.00     251.50     247.09     247.09      53.57     193.52
    4 20Dec64 12 Sun     216.64     216.64       0.00       0.03       3.00     251.50     263.09     263.09      62.57     200.52
    5 20Dec64 15 Sun     242.14     242.14       0.00       0.03       3.00     251.50     306.84     306.84      88.64     218.20
    6 20Dec64 18 Sun     271.87     271.87       0.00       0.03       3.00     251.50     345.51     345.51     102.40     243.11
    7 20Dec64 21 Sun     286.03     286.03       0.00       0.03       3.00     251.50     363.92     363.92      94.48     269.44
    8 20Dec64 24 Sun     290.28     290.28       0.00       0.03       3.00     251.50     378.07     378.07      94.10     283.97
    9 21Dec64  3 Mon     297.36     297.36       0.00       0.03       3.00     251.50     385.16     385.16      94.75     290.41
   10 21Dec64  6 Mon     297.36      80.00       0.00       0.00       3.01     251.73     361.67     397.90     101.70     259.97
   11 21Dec64  9 Mon     297.36      80.00       0.00       0.00       3.01     251.96     231.97     419.14     121.97     110.00
   12 21Dec64 12 Mon     417.72      80.00       0.00       0.00       3.02     252.33     277.37     509.76     192.37      85.00
   13 21Dec64 15 Mon     559.32      80.00       0.00       0.00       3.03     252.84     328.83     672.60     248.00      80.83
   14 21Dec64 18 Mon     715.08      80.00       0.00       0.00       3.05     253.52     447.63     930.32     367.49      80.14
   15 21Dec64 21 Mon     909.07      80.00       0.00       0.00       3.07     254.40     611.14    1253.16     531.12      80.02
   16 21Dec64 24 Mon     972.79      80.00       0.00       0.00       3.09     255.36     618.81    1427.33     538.81      80.00
   17 22Dec64  3 Tue    1005.36      80.00       0.00       0.00       3.12     256.34     553.07    1437.24     473.07      80.00
   18 22Dec64  6 Tue    1104.48      80.00       0.00       0.00       3.14     257.44     540.46    1475.48     460.46      80.00
   19 22Dec64  9 Tue    1260.24      80.00       0.00       0.00       3.18     258.70     588.63    1624.16     508.63      80.00
   20 22Dec64 12 Tue    1522.20      80.00       0.00       0.00       3.21     260.24     687.75    1887.53     607.75      80.00
   21 22Dec64 15 Tue    1932.84      80.00       0.00       0.00       3.26     262.19     836.43    2306.67     756.43      80.00
   22 22Dec64 18 Tue    2478.00      80.00       0.00       0.00       3.32     264.20    1014.37    2894.30     934.37      80.00
   23 22Dec64 21 Tue    2895.72      80.00       0.00       0.00       3.40     266.56    1116.24    3497.52    1036.24      80.00
   24 22Dec64 24 Tue    3086.88     104.75     104.75       0.20       3.47     269.05    1066.32    3837.36     982.19      84.13
   25 23Dec64  3 Wed    3016.08     283.26     283.26       0.20       3.54     271.24     946.13    3851.52     815.06     131.07
   26 23Dec64  6 Wed    2704.56     383.47     383.47       0.20       3.60     272.95     903.68    3596.64     629.08     274.60
   27 23Dec64  9 Wed    2400.12     370.09     370.09       0.20       3.66     274.44     837.29    3171.84     474.19     363.10
   28 23Dec64 12 Wed    2173.56     345.27     345.27       0.20       3.71     275.73     790.51    2837.67     425.72     364.79
   29 23Dec64 15 Wed    2095.68     344.79     344.79       0.20       3.75     276.96     865.44    2717.30     516.99     348.45
   30 23Dec64 18 Wed    2060.28     412.79     412.79       0.20       3.79     278.06     962.57    2713.06     605.84     356.73
   31 23Dec64 21 Wed    1947.00     500.73     500.73       0.20       3.83     278.98     995.56    2626.68     577.46     418.10
   32 23Dec64 24 Wed    1791.24     546.42     546.42       0.20       3.86     279.78     975.02    2418.53     480.45     494.57
   33 24Dec64  3 Thu    1748.76     561.30     561.30       0.20       3.89     280.54     994.40    2262.77     454.14     540.26
   34 24Dec64  6 Thu    1826.64     636.76     636.76       0.20       3.92     281.30    1086.91    2288.26     516.54     570.37
   35 24Dec64  9 Thu    1911.60     796.90     796.90       0.20       3.95     282.01    1278.91    2458.18     626.53     652.38
   36 24Dec64 12 Thu    1890.36     982.45     982.45       0.20       3.98     282.61    1473.38    2564.37     669.64     803.74
   37 24Dec64 15 Thu    1762.92    1099.13    1099.13       0.20       3.99     283.06    1559.02    2456.76     586.91     972.11
```

Table C.11 HEC-5 User Designed Output Table for Gated Spillway Operation (with **RG** Record, continued)

Location No=				44.	44.	44.	44.	44.	44.	40.	40.	40.	40.
				BISHOP DA	BISHOP DA	BISHOP DA	BISHOP DA	BISHOP DA	BISHOP DA	ZELMA	ZELMA	ZELMA	ZELMA
Per	Date:	Hr	Day	Inflow	Outflow	Q-Gate R	Case	Level	EOP Elev	Flow Reg	Natural	Loc Incr	Q by US
38	24Dec64	18	Thu	1593.00	1134.57	1134.57	0.20	4.04	283.35	1543.24	2211.79	459.37	1083.87
39	24Dec64	21	Thu	1437.24	1142.69	1119.45	0.21	4.09	283.53	1504.93	1971.07	377.46	1127.47
40	24Dec64	24	Thu	1345.20	1148.09	1093.50	0.21	4.12	283.65	1487.16	1794.07	346.11	1141.05
41	25Dec64	3	Fri	1295.64	1152.01	1096.68	0.21	4.14	283.74	1482.79	1689.29	335.22	1147.57
42	25Dec64	6	Fri	1267.32	1155.07	1121.44	0.21	4.16	283.80	1476.69	1625.57	324.91	1151.78
43	25Dec64	9	Fri	1217.76	1163.61	1163.61	0.20	4.17	283.83	1491.40	1600.08	335.46	1155.94
44	25Dec64	12	Fri	1161.12	1163.54	0.00	0.21	4.17	283.83	1540.61	1594.42	378.29	1162.32
45	25Dec64	15	Fri	1104.48	1161.97	0.00	0.21	4.16	283.80	1562.66	1560.43	399.58	1163.08
46	25Dec64	18	Fri	1047.84	1158.93	0.00	0.21	4.14	283.73	1511.45	1454.23	349.80	1161.65
47	25Dec64	21	Fri	984.12	1154.25	0.00	0.21	4.11	283.63	1444.40	1332.45	285.80	1158.60
48	25Dec64	24	Fri	934.56	1148.35	0.00	0.21	4.08	283.50	1442.12	1274.40	288.12	1154.00
49	26Dec64	3	Sat	899.16	1141.62	0.00	0.21	4.04	283.36	1448.47	1237.58	300.30	1148.17
50	26Dec64	6	Sat	856.68	1133.82	0.00	0.21	4.00	283.19	1429.59	1186.61	288.18	1141.41
51	26Dec64	9	Sat	825.53	979.67	0.00	0.22	4.00	283.08	1385.16	1134.22	275.77	1109.39
52	26Dec64	12	Sat	797.21	888.44	0.00	0.22	3.99	283.02	1268.52	1108.73	282.43	986.09
53	26Dec64	15	Sat	767.47	827.96	0.00	0.22	3.99	282.98	1203.43	1105.89	308.79	894.64
54	26Dec64	18	Sat	746.23	787.09	0.00	0.22	3.99	282.95	1153.71	1090.32	321.45	832.26
55	26Dec64	21	Sat	722.16	754.63	0.00	0.22	3.99	282.93	1120.79	1077.57	331.58	789.21
56	26Dec64	24	Sat	700.92	727.77	0.00	0.22	3.99	282.91	1100.98	1067.66	345.07	755.91
57	27Dec64	3	Sun	686.76	707.27	0.00	0.22	3.99	282.90	1052.06	1025.18	323.01	729.05
58	27Dec64	6	Sun	666.93	687.10	0.00	0.22	3.99	282.89	992.89	971.37	285.35	707.54
59	27Dec64	9	Sun	647.11	667.10	0.00	0.22	3.99	282.87	943.59	923.23	256.42	687.17
60	27Dec64	12	Sun	631.54	649.32	0.00	0.22	3.99	282.86	906.11	886.42	238.62	667.49
61	27Dec64	15	Sun	608.88	629.10	0.00	0.22	3.99	282.85	872.36	853.85	223.38	648.98
62	27Dec64	18	Sun	580.56	604.83	0.00	0.22	3.99	282.83	837.64	817.03	209.27	628.37
63	27Dec64	21	Sun	552.24	578.54	0.00	0.22	3.99	282.81	804.21	780.21	199.84	604.37
64	27Dec64	24	Sun	522.51	550.52	0.00	0.22	3.98	282.79	766.77	740.57	188.60	578.17
65	28Dec64	3	Mon	487.10	518.81	0.00	0.22	3.98	282.77	723.59	695.26	173.74	549.85
66	28Dec64	6	Mon	453.12	485.97	0.00	0.22	3.98	282.75	647.29	615.95	128.78	518.51
67	28Dec64	9	Mon	424.80	455.38	0.00	0.22	3.98	282.73	636.85	604.64	150.56	486.29
68	28Dec64	12	Mon	396.48	425.93	0.00	0.22	3.98	282.71	645.22	614.55	189.59	455.63
69	28Dec64	15	Mon	375.24	400.59	0.00	0.22	3.98	282.69	593.96	564.99	167.30	426.66
70	28Dec64	18	Mon	354.00	377.29	0.00	0.22	3.98	282.68	573.60	547.99	172.55	401.05
71	28Dec64	21	Mon	325.68	351.49	0.00	0.22	3.98	282.66	553.68	529.58	176.73	376.95
72	28Dec64	24	Mon	297.36	324.42	0.00	0.22	3.98	282.64	524.16	498.43	172.94	351.22
			Sum =	76684.89	39013.56	14097.36	10.62	264.99	19657.26	64394.97	102093.05	25518.57	38876.41
			Max =	3086.88	1163.61	1163.61	0.22	4.17	283.83	1562.66	3851.52	1036.24	1163.08
			Min =	192.58	80.00	0.00	0.00	3.00	251.50	231.97	241.85	49.27	80.00
			PMax=	24.00	43.00	43.00	51.00	43.00	43.00	45.00	25.00	23.00	45.00
			Avg =	1065.07	541.86	195.80	0.15	3.68	273.02	894.37	1417.96	354.42	539.95
			PMin=	1.00	10.00	1.00	10.00	1.00	1.00	11.00	1.00	1.00	16.00

C.2 Multiple Reservoir System Simulation

A four-reservoir system is used to demonstrate flood control system operation in HEC-5. Flood control simulations are accomplished by balancing the reservoir levels above a common downstream control point according to the user specified target levels on the **RL** Records. The four-reservoir system is also used to illustrate reservoir guide curve options, varying channel capacity options and the various channel routing techniques available. These options may also be used for single reservoirs.

C.2.1 Four-Reservoir System Model (Example 3)

Figure C.4 is a schematic of four reservoirs operating as a system to reduce flooding at three common downstream locations.

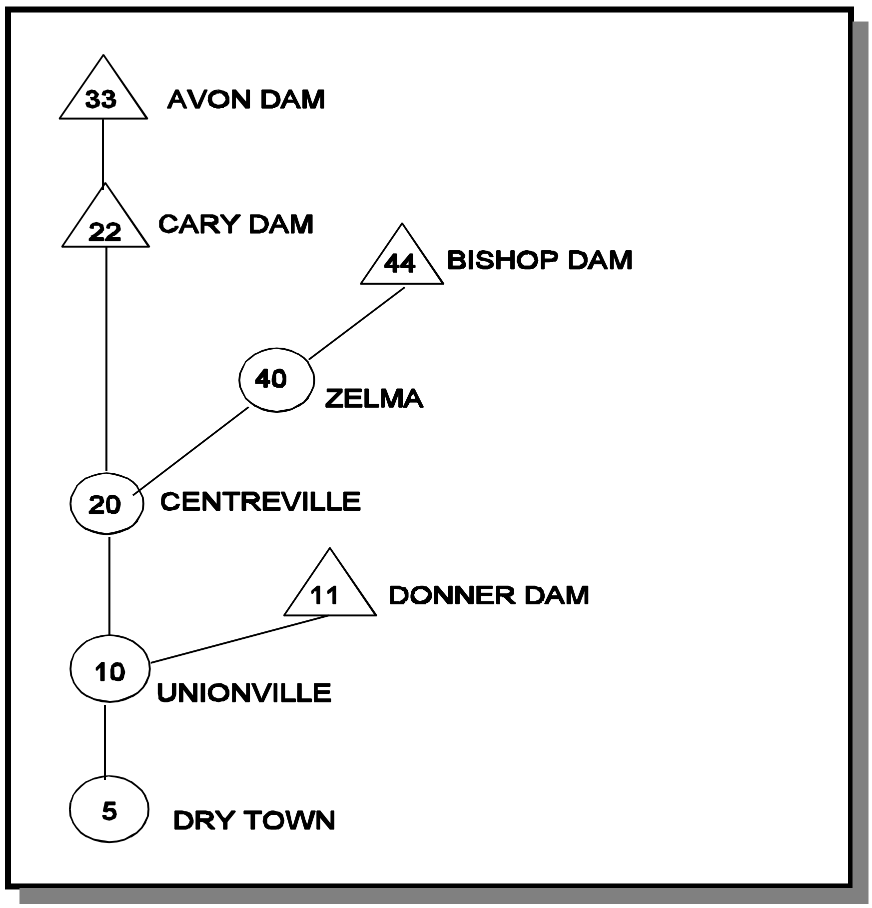

Figure C.4 Four-Reservoir System (Example 3)

Reservoir storage allocations, storage-outflow-elevation relationships, operational criteria and routing criteria (**RL**-**RT** Records) are given for each of the four reservoirs. The general rule for ordering the input data is simply described as adding reservoirs and control points to the data in a "top-to- bottom" sequence. However, when developing an input model such as Example 3, with both tandem and parallel reservoirs, a more thoughtful approach is beneficial. In this example, the order of input was guided by two additional rules: the outer tandem reservoirs should be added first (reservoir 33); and, the most complex (e.g., operationally constrained) branches (44 and 40) should have a high priority for addition. The input sequence for Example 3 is: 33, 44, 40, 22, 20, 11, 10, and 5. The **RO** Records, which define the locations reservoirs consider, are especially important in multi-reservoir operation. Rules for use of the **RO** Record are described in Appendix G, Input Description. In this example, reservoir 33 operates for reservoir 22 (tandem operation). Reservoirs 22, 44 and 11 each operate for all of their downstream control points. By default, each reservoir operates for itself and need not be specified on the **RO** Record.

Daily incremental local flows (**J3** Record, field 6 = 1) are being read from HEC-DSS (**ZR** Record) at all locations. Natural flows are being calculated for comparison purposes (**J2** Record, field 4 = -1).

Table C.12 lists the HEC-5 input file (EXAMPLE3.DAT) of the four-reservoir system and Table C.13 shows two schematic maps that are produced in the output file. *Map 1 summarizes the locations being operated for by upstream reservoirs. *Map 2 is a summary of pertinent input data including channel capacities and flood storage allocations.

In Example 3, all levels remain the same during the year except for the top-of-conservation pool (level 3) which varies as follows:

Reservoir 33 varies seasonally (9 seasons)
Reservoir 22 varies seasonally (6 seasons)

Table C.12 HEC-5 Input for a Basic Four-Reservoir System (Example 3)

```
T1      HEC-5 Example 3, Four Reservoir System     (EXAMPLE3.DAT)
T2      Tandem and Parallel Reservoir System with Variable Channel Capacities
T3      Rocky River Basin, Avon Dam to Dry Town
J1       1       1       5       3       4       2
J2      24     1.2               8       0      10
J3       5                      -1              -1
J8 44.10   44.12   44.13   22.13   22.12   22.10   20.18   40.18   10.18    5.18
J8 33.10   33.12   33.13   22.13   22.12   22.10   22.17   22.22   20.04   10.04
J8 44.10   22.10   11.10   44.13   22.13   11.13   44.12   22.12   11.12    5.04
JZ-44.13   33.13   22.13   11.13   44.10   33.10   22.10   11.10   40.17   20.17
JZ 40.04   20.04   10.04    5.04   40.02   20.02   10.02    5.02   10.17    5.17
JR     0     1.7     600    1200    1800
JR    33     1.7     600    1800

C  ============== Avon Dam =============
RL    33  151400   31100   34050  151400  350550  375000
RL     1      33      -1       0   31100
RL     2      33      -1       0   34050
RL     3      33       9       0  151400  151400  197000  310330  310330  254050
RL                                210500  151400  151400
RL     4      33      -1       0  350550
RL     5      33      -1       0  375000
RO     1      22
RS    11       0   31100   34050   53000  100240  151400  201100  256350  297100
RS350550  375000
RQ    11       0      11     145     178     212     240     452     664    1457
RQ  1646    1829
RE    11     309   349.6     351   362.1     370   374.3   377.4     382     383
RE 384.7   386.8
R2    20      60
CP    33     150       3     1.5
IDAVON DAM
RT    33      22     2.2    0.25     3.2
CS     9       1     105     135     151     250     274     305     331     365

C  ============== Bishop Dam Site =============
RL    44  146480  131438  134000  146480  562248  630063
RO     4      40      20      10       5
RS    13       0  124113  131438  134000  146480  253628  362008  417740  465211
RS546342  562248  589251  630063
RQ    13       0     333     665     668     681     796     872     912    2322
RQ  5664    6457    7646    9629
RE    13   209.7   249.6   250.2   250.4   251.5   262.1   270.5   274.3   277.4
RE 282.2   283.2   284.7   286.8
R2    10      60
CP    44     425      20       2
IDBISHOP DAM
RT    44      40     1.2     0.3     3.0

C  ============== Zelma ===============
CP    40     450
IDZELMA
RT    40      20     1.9
CR     3     .10     .65     .25
```

... Continued ...

Table C.12 HEC-5 Input for Four Reservoir System (Example 3, Continued)

... Continuation of Example 3 ...

```
C  ============== Cary Dam =============
RL    22  255480   21438  134000  255480  389190  435563
RL     1      22      -1       0   21438
RL     2      22      -1       0  134000
RL     3      22       6       0  255480  255480  362008  362008  255480  255480
RL     4      22      -1       0  389248
RL     5      22      -1       0  435563
RO     3      20      10       5
RS     9       0   21438  134000  255480  362008  375600  378300  389190  435563
RQ     9       0     657     681     796     872     892     896     912    2322
RE     9     259   309.6   302.5   312.1   320.5   322.4   322.8   324.3   327.4
R2    15      30
CP    22     100     2.2       1
IDCARY DAM
RT    22      20     2.2    0.45     3.1
CC  22.5     100     100     150     150
CS     6       1     105     151     250     305     365
CG -4.10     309     309     309     309     309     309
CG -4.11   312.1   312.1   320.5   320.5   312.1   312.1
CG -2.25   317.1   317.1   325.5   325.5   317.1   317.1
CG -4.35   327.4   327.4   327.4   327.4   327.4   327.4

C  ============== Centerville ==============
CP    20     550
IDCENTERVILLE
RT    20      10     1.2    0.35     3.0

C  ============== Donner Reservoir =============
RL    11   56480    1638    4000   56480  150200  215000
RO     2      10       5
RS     8       0    1638    4000   56480   93008  112740  150200  215000
RQ     8       0     657     681     796     872     912    2322    5664
RE     8    59.7    99.6   101.5   112.1   120.5   124.3   127.4   132.2
R2   100     100
CP    11     100     1.1      .5
IDDONNER DAM
RT    11      10     3.2     0.2     3.0
CL     6     1.0     3.0     3.1    3.59     3.8     5.0
CC  11.4      25      25     100     100     150     150

C  ============== Unionville ==========
CP    10     870
IDUNIONVILLE
RT    10       5     1.4     0.2       0
QS     9       0     200     300     540     740     920    1150    1480    3000
SQ     9       0     400     640    1050    1550    1850    3250    4500    6200

C  ============== Dry Town ============
CP     5     950
IDDRY TOWN
RT     5

ED
C    ------------------- Flood of Jan 21-29 1955 ------------------------------
BF     2      72       0        55012100       0       3
ZR=IN   A=EXAMPLE 3    C=FLOW-LOC INC   F=COMPUTED FLOWS
ZW      A=EXAMPLE 3         F=SYSTEM OPERATION
EJ
ER
```

Table C.13 Schematic Maps from Output File Showing Pertinent Input Data (Example 3)

```
*Map 1

          HEC-5 Example 3, Four Reservoir System     (EXAMPLE3.DAT)

                                 Upstream Reservoirs Operating for Each Location

    33R              AVON DAM
    22R              CARY DAM          33
     |     .----44R  BISHOP DAM
     .----40         ZELMA             44
    20               CENTERVILL        44      22
     .----11R        DONNER DAM
    10               UNIONVILLE        44      22      11
     5               DRY TOWN          44      22      11


------------------------------------------------------------------------------------------------------------


*Map 2

          HEC-5 Example 3, Four Reservoir System     (EXAMPLE3.DAT)

                                   Channel    Flood    Conserv.  Min Des.  Min Req.  Divert     Map  Location
                                   Capacity  Storage   Storage     Flow      Flow      to     Number   Name

    33R              AVON DAM          150.   199150.   120300.        3.        2.       0       33 AVON DAM
    22R              CARY DAM          100.   133768.   234042.        2.        1.       0       22 CARY DAM
     |     .----44R  BISHOP DAM        425.   415768.    15042.       20.        2.       0       44 BISHOP DAM
     .----40         ZELMA             450.        0.        0.        0.        0.       0       40 ZELMA
    20               CENTERVILL        550.        0.        0.        0.        0.       0       20 CENTERVILLE
     .----11R        DONNER DAM         25.    93720.    54842.        1.        1.       0       11 DONNER DAM
    10               UNIONVILLE        870.        0.        0.        0.        0.       0       10 UNIONVILLE
     5               DRY TOWN          950.        0.        0.        0.        0.       0        5 DRY TOWN
```

Additional **RL** Records are required for Reservoir 33 and Reservoir 22, for each level. However, for those levels that remain constant throughout the year (levels 1, 2, 4 and 5), a value of -1 is specified in field 3 of the **RL** Record and the storage value for that level is input in field 5. For the level that varies by season (level 3 in this example), a **CS** Record is required to define the seasons that correspond to the input storage values on the **RL** Record for level 3. HEC-5 uses linear interpolation between storage values. Table C.14 contains the "*Rule Curve Summary" produced in the Example 3 output file. It shows the season dates and the corresponding storage values for the five reservoir levels at all of the reservoirs. Figure C.5 shows an HEC-DSS plot of the reservoir guide curves at the two reservoirs where the top-of-conservation varies seasonally.

Channel Capacity Options. The channel capacity at any location can be constant or vary as shown in Table C.15. In Example 3, Reservoir 11 illustrates channel capacity at the reservoir based on reservoir level alone (option 4). The reservoir level can be at any specified reservoir; however, in this example it is the same reservoir. Table C.16 shows the input records for specifying the channel capacity for Reservoir 11 based on its Level. The program uses linear interpolation between the six points defining the reservoir levels (on **CL** Record) and the channel capacities (on **CC** Record).

Channel capacity varying seasonally with reservoir level or elevation (option 5) is used for Reservoir 22. A discussion of the channel capacity rule curve operation and its variations is given in Appendix G, Input Description for the **CG** Record. Table C.17 shows the input records for Reservoir 22. Six seasons are input on the **CS** Record, four channel capacities are entered on the **CC** Record, and one **CG** Record is given for each of the four values specified on the **CC** Record. The **CG** Records are input in the same order as the values on the **CC** Record. The code (to the left of the decimal point) in the first field of the **CG** Record determines the method by which the channel capacity is to be interpolated within reservoir zones. A negative value indicates reservoir elevations (instead of reservoir levels) are being specified in the remaining fields of the **CG** Record. The value of -4.10 for the first **CG** Record signifies that the top-of-the zone is used to define the channel capacity for the reservoir elevations given on the remainder of the **CG** Record.

Table C.14 Summary of Input Reservoir Storage Values for Five Levels (Example 3)

```
*Rule Curve Summary

   Initial   Cum     Start               Storage for Level:
   Storage   Days    Date        1         2         3         4         5


           -----------------------------------------
           Reservoir Number =   33     AVON DAM
           -----------------------------------------

   151400.     1    01 JAN    31100.    34050.   151400.   350550.   375000.

Season = 2   105    15 APR    31100.    34050.   151400.   350550.   375000.

         3   135    15 MAY    31100.    34050.   197000.   350550.   375000.

         4   151    31 MAY    31100.    34050.   310330.   350550.   375000.

         5   250    07 SEP    31100.    34050.   310330.   350550.   375000.

         6   274    01 OCT    31100.    34050.   254050.   350550.   375000.

         7   305    01 NOV    31100.    34050.   210500.   350550.   375000.

         8   331    27 NOV    31100.    34050.   151400.   350550.   375000.

         9   365    31 DEC    31100.    34050.   151400.   350550.   375000.


           -----------------------------------------
           Reservoir Number =   44     BISHOP DAM
           -----------------------------------------

   146480.     1    01 Jan   131438.   134000.   146480.   562248.   630063.


           -----------------------------------------
           Reservoir Number =   22     CARY DAM
           -----------------------------------------

   255480.     1    01 JAN    21438.   134000.   255480.   389248.   435563.

Season = 2   105    15 APR    21438.   134000.   255480.   389248.   435563.

         3   151    31 MAY    21438.   134000.   362008.   389248.   435563.

         4   250    07 SEP    21438.   134000.   362008.   389248.   435563.

         5   305    01 NOV    21438.   134000.   255480.   389248.   435563.

         6   365    31 DEC    21438.   134000.   255480.   389248.   435563.


           -----------------------------------------
           Reservoir Number =   11     DONNER DAM
           -----------------------------------------

    56480.     1    01 Jan     1638.     4000.    56480.   150200.   215000.
```

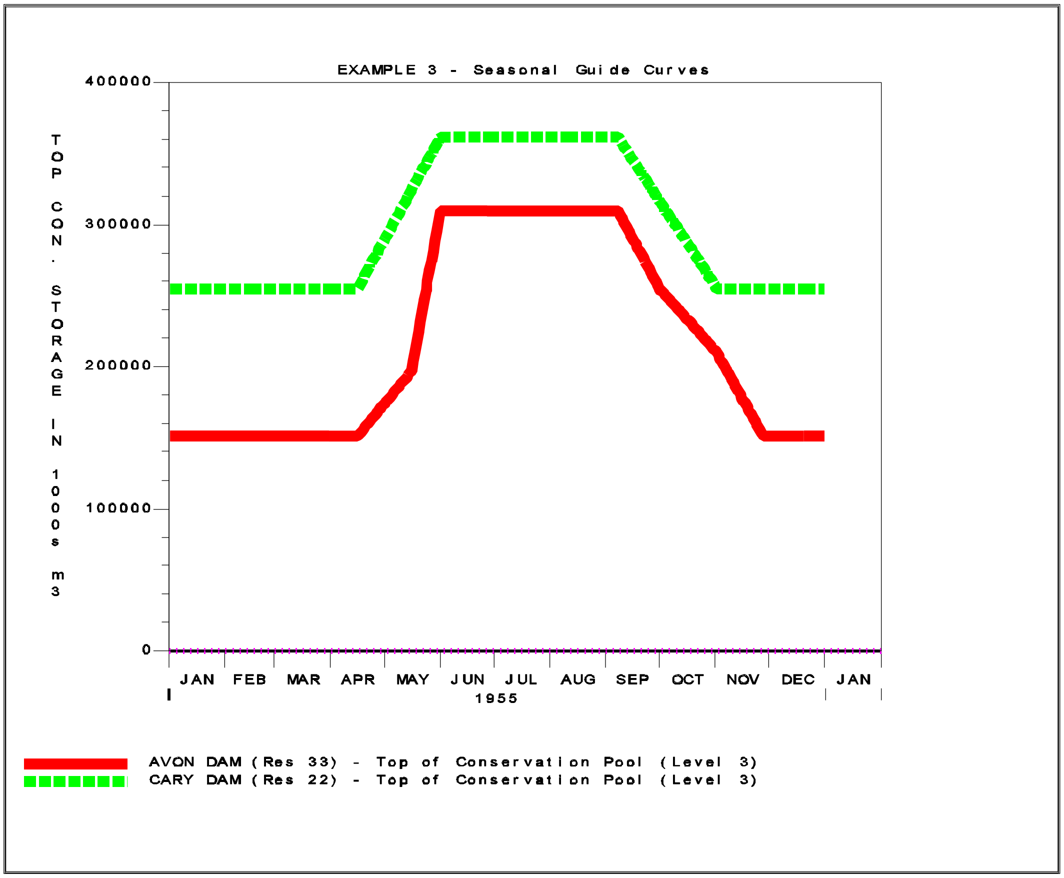

Figure C.5 Seasonal Guide Curves for Reservoirs 33 and 22 (Example 3)

Table C.15 Options for Varying Channel Capacities

Option	Description	Records
1	Monthly	CC
2	Seasonally	CC, CS
3	Function of flow at another location	CC, QS
4	Function of reservoir level	CC, CL
5	Function of season and level	CC, CS, CG
6	Function of season and percent system flood control storage	CC, CS, CG, GC
7	Varies with rising or falling inflow	CC

Table C.16 Channel Capacity Based on Reservoir Level (Reservoir 11)

CL	6	1.0	3.0	3.1	3.59	3.8	5.0
CC	11.4	25	25	100	100	150	150

Table C.17 Channel Capacity Based on Seasons and Reservoir Elevation (Reservoir 22)

The following are input records for Specifying Channel Capacity for Reservoir 22:

```
 CC  22.5     100     100     150     150
 CS     6       1     105     151     250     305     365
 CG -4.10     309     309     309     309     309     309
 CG -4.11   312.1   312.1   320.5   320.5   312.1   312.1
 CG -2.25   317.1   317.1   325.5   325.5   317.1   317.1
 CG -4.35   327.4   327.4   327.4   327.4   327.4   327.4
```

The following summary is produced in the Output file:

```
                                   --------------
 Channel Capacity GUIDE CURVE for: Location =  22  Based on: REFERENCE Location = 22
================                  --------------

Seasons (in Days Since 31 Dec):        1.    105.    151.    250.    305.    365.
                 Starting Date:    01 JAN  15 APR  31 MAY  07 SEP  01 NOV  31 DEC
       .... CODE  ....
 Zone  Rising  Falling   Chan Cap    Reservoir  ELEVATION  Data for Zones
 ---------------------
   1     4        4
 ---------------------      100.   309.00  309.00  309.00  309.00  309.00  309.00
   2     4        4
 ---------------------      100.   312.10  312.10  320.50  320.50  312.10  312.10
   3     2        2
 ---------------------      150.   317.10  317.10  325.50  325.50  317.10  317.10
   4     4        4
 ---------------------      150.   327.40  327.40  327.40  327.40  327.40  327.40
```

C.2.2 HEC-5 Results for Example 3

Example 3 is a four-reservoir system model which illustrates the operation of reservoirs to reduce flooding at downstream locations while maintaining specified low-flow requirements. To analyze HEC-5 flood system simulation results, the HEC-5 output features which are the most useful are: (1) the "Summary of Maximums" tables; (2) the **J8**/**JZ** User Designed Output tables; and (3) graphical plots generated using the HEC-DSS program DSPLAY.

The "Summary of Maximums" tables (requested by **J3** Record, field 1) are shown in Table C.18 and Table C.19.

Table C.18 Summary of Maximum Values for Reservoirs (Example 3)

```
                                        --------------
                Summary of Maximums for    RESERVOIRS
                           --------     --------------


      HEC-5 Example 3, Four Reservoir System     (EXAMPLE3.DAT)
      Tandem and Parallel Reservoir System with Variable Channel Capacities
      Rocky River Basin, Avon Dam to Dry Town

           -------------------------------------------------------

           Period of Analysis:  STARTING :  21JAN55 - 0000 Hrs
                                ENDING   :  29JAN55 - 2400 Hrs
                                DURATION :  9 Days,  0 Hrs,  0 Min

                Time Interval:    3 Hours,  0 Minutes

           -------------------------------------------------------

******************************************************************************
*    Reservoir    *    Max    *    Max    *   Max              *    Max     *
*                 *   Inflow  *  Outflow  * Storage    Elev    *   HEC-5    *
*  ID    Name     *   (m3/s)  *  (m3/s)   * (1000m3)  (Meters)*    Levels   *
*                 *           *           *                    *            *
******************************************************************************
*                 *           *           *                    *            *
*  33 AVON DAM    *       741 *       150 *   315714   383.59 *      3.825 *
*                 * 22JAN-2100 * 22JAN-0600 *    29JAN-1500     * 29JAN-1500 *
*                 *           *           *                    *            *
*  44 BISHOP DAM  *      1544 *       333 *   493315   279.06 *      3.834 *
*                 * 22JAN-2100 * 29JAN-1800 *    28JAN-0600     * 28JAN-0600 *
*                 *           *           *                    *            *
*  22 CARY DAM    *       623 *       150 *   366517   321.13 *      3.830 *
*                 * 23JAN-0600 * 26JAN-1800 *    29JAN-0300     * 29JAN-0300 *
*                 *           *           *                    *            *
*  11 DONNER DAM  *       355 *       113 *   117025   124.65 *      3.646 *
*                 * 23JAN-1800 * 26JAN-1200 *    26JAN-1200     * 26JAN-1200 *
*                 *           *           *                    *            *
******************************************************************************


           Maximum System Storage Used =  1281593.  (28JAN-0300)
```

Table C.19 Summary of Maximum Values for Control Point Locations (Example 3)

Summary of Maximums for CHANNEL CONTROL POINT LOCATIONS

HEC-5 Example 3, Four Reservoir System (EXAMPLE3.DAT)
Tandem and Parallel Reservoir System with Variable Channel Capacities
Rocky River Basin, Avon Dam to Dry Town

Period of Analysis: STARTING : 21JAN55 - 0000 Hrs
ENDING : 29JAN55 - 2400 Hrs
DURATION : 9 Days, 0 Hrs, 0 Min

Time Interval: 3 Hours, 0 Minutes

Channel Location ID	Name	**Channel Capacity** (m3/s)	**Max Reg. Flow** (m3/s)	Q from Res. (m3/s)	Max Cum. Local Q (m3/s)	Max Natural Q (m3/s)
33	AVON DAM	150	150 22JAN-0600	0	741 22JAN-2100	741 22JAN-2100
44	BISHOP DAM	425	333 29JAN-1800	0	1544 22JAN-2100	1544 22JAN-2100
22	CARY DAM	150	150 26JAN-1800	0	494 23JAN-0600	1193 23JAN-0600
11	DONNER DAM	113	113 26JAN-1200	0	355 23JAN-1800	355 23JAN-1800
40	ZELMA	450	538 23JAN-1200	20	518 23JAN-1200	1788 23JAN-0300
20	**CENTERVILLE**	**550**	**771** 23JAN-1800	22	748 23JAN-1800	3055 23JAN-1200
10	UNIONVILLE	870	909 23JAN-2100	23	886 23JAN-2100	3340 23JAN-1500
5	DRY TOWN	950	1036 23JAN-2100	23	1013 23JAN-2100	3447 23JAN-1800

Table C.18 shows Reservoir maximum values of storages, elevations, and levels, as well as maximum inflow and outflow values. In Example 3, the flood control storage zone is defined as being between level 3 and level 4 (see **J1** Record, fields 4 and 5). A review of Table C.18 indicates that the maximum flood control storage level in each of the three upper reservoirs (Avon, Bishop, and Cary) was 3.83 (flood storage 83% full). The fact that each of the three upper reservoirs achieved the same utilization of their flood storage is indicative of a strong integrated system operation. The lowest reservoir in the system (Donner), however, utilized only 65% (level 3.65) of its flood control storage.

To answer why Donner utilized significantly less flood storage and reached its maximum level several days earlier, additional output must be reviewed. The output listed in Table C.19 suggests that flooding in the system was the most severe at Centerville, which had a maximum regulated flow of 771 m^3/s and a channel capacity of 550 m^3/s. We can surmise that since Donner is in the lower portion of the basin and it does not operate for Centerville, it was able to make releases to evacuate its flood storage pool more frequently; or, perhaps runoff in the lower basin was significantly less than in the upper basin. The "Summary of Maximums" tables do not provide definitive answers to these operation questions.

The most informative output are the "User Designed" output tables which show selected program results for each time period of the simulation. Program users may create these tables by choosing from 41 output variable codes. These tables are created using the **J8** and/or **JZ** Records where location numbers and codes are specified (e.g., 44.10 requests reservoir 44's outflow). Table C.20 is an example of a thoughtfully developed user designed table. The three most essential reservoir output items (Outflow, Case and Level), which explain reservoir release decisions, are shown for the two *parallel* reservoirs (Bishop and Cary) in the upper basin. Also shown are the available flood space (Q Space) at the four downstream locations for which the reservoirs operate.

The second user designed table (Table C.21) shows similar information for the two *tandem* reservoirs (Avon and Cary). Because the channel capacity at Cary Dam varies with elevation, this table also shows its elevation and channel capacity along with the regulated flows at Centerville and Unionville. Table C.22 shows Outflow, Level and Case for all three of the *parallel* reservoirs (Bishop, Cary and Donner) as well as the regulated flow at Dry Town, their common operation point.

Because Bishop and Cary Dams operate for a common downstream location (Centerville), an analysis of their operation can be made by reviewing Table C.20. Notice that in Period 12 the Cary Dam Outflow was reduced from 103.2 m^3/s to 69.19 m^3/s. The Cary Dam Case shown for this period is 20.03 which indicates the decision was based on a forecast of flooding at location 20 (Centerville) three periods in the future. Release from Bishop Dam was increased during period 12 from 28.5 m^3/s to 58.5 m^3/s. The Bishop Dam Case for this period is 0.02 which indicates it was based on the rate-of-change for increasing releases (see **R2** Record, field 1).

Table C.20 User Designed Output: Parallel Operation of Bishop Dam and Cary Dam for Centerville (Example 3)

*USERS. 1   User Designed Output   (Dates shown are for END-of-Period)

Summary by Period   Flood=   1

Location No=				44.	44.	44.	22.	22.	22.	20.	40.	10.	5.
J8/JZ Codes=				44.100	44.120	44.130	22.130	22.120	22.100	20.180	40.180	10.180	5.180
				BISHOP D	**BISHOP D**	**BISHOP D**	**CARY DAM**	**CARY DAM**	**CARY DAM**	**CENTERVIL**	ZELMA	UNIONVILL	DRY TOWN
Per	Date:	Hr	Day	**Outflow**	**Case**	**Level**	**Level**	**Case**	**Outflow**	**Q Space**	Q Space	Q Space	Q Space
1	21Jan55	3	Fri	148.50	0.03	3.00	3.00	0.01	100.02	257.73	270.00	546.36	616.86
2	21Jan55	6	Fri	148.50	0.03	3.00	3.00	0.01	100.02	255.18	257.00	545.00	614.17
3	21Jan55	9	Fri	148.50	-0.01	3.00	3.00	-0.01	100.02	243.83	250.50	541.19	609.72
4	21Jan55	12	Fri	178.50	0.02	3.00	3.00	0.01	100.02	229.76	249.50	529.93	600.16
5	21Jan55	15	Fri	178.50	-0.01	3.01	3.00	-0.01	100.02	222.15	228.67	515.36	583.79
6	21Jan55	18	Fri	208.50	0.02	3.02	3.00	0.01	100.02	209.46	219.69	503.98	571.84
7	21Jan55	21	Fri	208.50	-0.01	3.02	3.01	-0.01	100.02	195.93	194.78	485.92	555.06
8	21Jan55	24	Fri	208.50	-0.01	3.03	3.02	-0.01	100.02	175.88	181.21	468.57	535.11
9	22Jan55	3	Sat	208.50	-0.01	3.04	3.03	-0.01	100.02	155.53	145.62	450.38	515.64
10	22Jan55	6	Sat	28.50	0.02	3.05	3.04	0.01	103.02	124.18	147.52	428.44	487.03
11	22Jan55	9	Sat	**28.50**	-0.01	**3.07**	**3.05**	-0.01	**103.02**	106.22	221.32	399.47	455.53
12	22Jan55	12	Sat	**58.50**	**0.02**	**3.10**	**3.07**	**20.03**	**69.19**	138.30	221.99	384.66	439.96
13	22Jan55	15	Sat	58.50	-0.01	3.13	3.09	-0.01	69.19	125.88	189.46	402.50	456.33
14	22Jan55	18	Sat	**20.00**	0.00	3.17	3.12	0.00	**2.20**	90.64	177.83	382.02	443.80
15	22Jan55	21	Sat	20.00	-0.01	3.20	3.16	-0.01	2.20	**82.16**	194.75	352.32	405.79
16	22Jan55	24	Sat	20.00	-0.01	3.24	3.20	-0.01	2.20	160.25	174.62	348.15	396.59
17	23Jan55	3	Sun	20.00	-0.01	3.28	3.25	-0.01	2.20	156.84	125.85	398.45	424.36
18	23Jan55	6	Sun	20.00	0.00	3.31	3.30	0.00	2.20	101.15	51.98	387.52	408.94
19	23Jan55	9	Sun	20.00	-0.01	3.34	3.35	-0.01	2.20	7.34	**-37.00**	324.43	329.27
20	23Jan55	12	Sun	20.00	0.00	3.36	3.39	0.00	2.20	**-111.06**	**-88.00**	222.99	227.47
21	23Jan55	15	Sun	20.00	-0.01	3.39	3.43	-0.01	2.20	**-208.25**	**-61.00**	101.06	88.88
22	23Jan55	18	Sun	20.00	0.00	3.41	3.46	0.00	2.20	**-220.60**	22.50	0.40	**-31.38**
23	23Jan55	21	Sun	20.00	-0.01	3.44	3.49	-0.01	2.20	**-136.78**	115.50	**-38.88**	**-86.43**
24	23Jan55	24	Sun	20.00	-0.01	3.46	3.52	-0.01	2.20	**-11.95**	133.00	2.50	**-59.01**
25	24Jan55	3	Mon	20.00	-0.01	3.48	3.55	-0.01	2.20	30.58	147.00	89.95	13.96
26	24Jan55	6	Mon	20.00	0.00	3.51	3.57	0.00	2.20	52.25	141.50	149.08	39.98
27	24Jan55	9	Mon	20.00	-0.01	3.53	3.59	-0.01	2.20	63.72	137.00	186.30	28.51
28	24Jan55	12	Mon	20.00	0.00	3.55	3.62	0.00	2.20	67.13	141.50	205.53	26.54
29	24Jan55	15	Mon	20.00	-0.01	3.57	3.64	-0.01	2.20	88.52	160.00	223.40	55.20
30	24Jan55	18	Mon	20.00	0.00	3.59	3.66	0.00	2.20	99.22	163.00	251.11	93.73
31	24Jan55	21	Mon	20.00	-0.01	3.61	3.69	-0.01	2.20	108.90	171.50	277.78	128.11
32	24Jan55	24	Mon	20.00	-0.01	3.62	3.71	-0.01	2.20	114.17	176.50	291.16	152.45
33	25Jan55	3	Tue	20.00	-0.01	3.64	3.73	-0.01	2.20	116.65	185.00	300.65	162.99
34	25Jan55	6	Tue	41.43	20.02	3.66	3.74	0.02	47.20	121.67	192.93	306.67	187.21
35	25Jan55	9	Tue	41.43	-0.01	3.67	3.75	-0.01	47.20	117.44	182.05	304.94	194.25
36	25Jan55	12	Tue	21.81	5.01	3.68	3.76	0.02	92.20	79.17	213.84	276.42	177.78
37	25Jan55	15	Tue	21.81	-0.01	3.70	3.77	-0.01	92.20	95.59	252.55	230.62	137.44

Table C.21 User Designed Output: Tandem Operation of Avon Dam for Cary Dam (Example 3)

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*USERS. 2    User Designed Output    (Dates shown are for END-of-Period)

                                       Summary by Period   Flood=      1
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Per	Date:	Hr	Day	**AVON DAM Outflow**	**AVON DAM Case**	**AVON DAM Level**	**CARY DAM Level**	CARY DAM Case	CARY DAM Outflow	CARY DAM QMax-Tar	CARY DAM EOP Elev	CENTERVIL Flow Reg	UNIONVILL Flow Reg
Location No=				33.	33.	33.	22.	22.	22.	22.	22.	20.	10.
J8/JZ Codes=				33.100	33.120	33.130	22.130	22.120	22.100	22.170	22.220	20.040	10.040
1	21Jan55	3	Fri	71.28	0.03	3.00	3.00	0.01	100.02	100.02	312.11	292.27	323.64
2	21Jan55	6	Fri	45.76	0.05	3.00	3.00	0.01	100.02	100.02	312.12	294.82	325.00
3	21Jan55	9	Fri	45.76	-0.01	3.00	3.00	-0.01	100.02	100.02	312.13	306.17	328.81
4	21Jan55	12	Fri	45.76	-0.01	3.01	3.00	0.01	100.02	100.02	312.13	320.24	340.07
5	21Jan55	15	Fri	45.76	-0.01	3.02	3.00	-0.01	100.02	100.02	312.12	327.85	354.64
6	21Jan55	18	Fri	105.76	0.02	3.02	3.00	0.01	100.02	100.02	312.13	340.54	366.02
7	21Jan55	21	Fri	105.76	-0.01	3.03	3.01	-0.01	100.02	100.02	312.17	354.07	384.08
8	21Jan55	24	Fri	105.76	-0.01	3.04	3.02	-0.01	100.02	100.02	312.26	374.12	401.43
9	22Jan55	3	Sat	105.76	-0.01	3.04	3.03	-0.01	100.02	101.02	312.38	394.47	419.62
10	22Jan55	6	Sat	150.00	0.01	3.05	3.04	0.01	103.02	103.02	312.51	425.82	441.56
11	22Jan55	9	Sat	150.00	-0.01	3.06	3.05	-0.01	103.02	104.02	312.65	443.78	470.53
12	22Jan55	12	Sat	150.00	-0.01	3.08	3.07	20.03	69.19	106.02	312.86	411.70	485.34
13	22Jan55	15	Sat	150.00	-0.01	3.11	3.09	-0.01	69.19	108.02	313.10	424.12	467.50
14	22Jan55	18	Sat	150.00	0.01	3.14	3.12	0.00	2.20	110.02	313.41	459.36	487.98
15	22Jan55	21	Sat	150.00	-0.01	3.17	3.16	-0.01	2.20	114.02	313.80	467.84	517.68
16	22Jan55	24	Sat	150.00	-0.01	3.20	3.20	-0.01	2.20	118.02	314.26	389.75	521.85
17	23Jan55	3	Sun	**150.00**	-0.01	**3.23**	**3.25**	-0.01	2.20	123.02	314.78	393.16	471.55
18	23Jan55	6	Sun	**58.62**	**0.05**	**3.25**	3.30	0.00	2.20	128.02	315.31	448.85	482.48
19	23Jan55	9	Sun	58.62	-0.01	3.28	3.35	-0.01	2.20	133.02	315.82	542.66	545.57
20	23Jan55	12	Sun	58.62	-0.01	3.30	3.39	0.00	2.20	139.02	316.25	661.06	647.01
21	23Jan55	15	Sun	58.62	-0.01	3.33	3.43	-0.01	2.20	143.02	316.64	758.25	768.94
22	23Jan55	18	Sun	**3.00**	0.00	3.35	3.46	0.00	2.20	147.02	316.97	770.60	869.60
23	23Jan55	21	Sun	3.00	-0.01	3.38	3.49	-0.01	2.20	150.04	317.29	686.78	908.88
24	23Jan55	24	Sun	3.00	-0.01	3.40	3.52	-0.01	2.20	150.04	317.59	561.95	867.50
25	24Jan55	3	Mon	3.00	-0.01	3.42	3.55	-0.01	2.20	150.04	317.86	519.42	780.05
26	24Jan55	6	Mon	3.00	0.00	3.45	3.57	0.00	2.20	150.04	318.10	497.75	720.92
27	24Jan55	9	Mon	3.00	-0.01	3.47	3.59	-0.01	2.20	150.04	318.34	486.28	683.70
28	24Jan55	12	Mon	3.00	-0.01	3.49	3.62	0.00	2.20	150.04	318.59	482.88	664.47
29	24Jan55	15	Mon	3.00	-0.01	3.51	3.64	-0.01	2.20	150.04	318.85	461.48	646.60
30	24Jan55	18	Mon	3.00	0.00	3.53	3.66	0.00	2.20	150.04	319.11	450.78	618.89
31	24Jan55	21	Mon	3.00	-0.01	3.55	3.69	-0.01	2.20	150.04	319.35	441.10	592.22
32	24Jan55	24	Mon	3.00	-0.01	3.57	3.71	-0.01	2.20	150.04	319.57	435.83	578.84
33	25Jan55	3	Tue	3.00	-0.01	3.58	3.73	-0.01	2.20	150.04	319.76	433.35	569.35
34	25Jan55	6	Tue	3.00	0.00	3.60	3.74	0.02	47.20	150.04	319.91	428.33	563.33
35	25Jan55	9	Tue	3.00	-0.01	3.61	3.75	-0.01	47.20	150.04	320.05	432.56	565.06
36	25Jan55	12	Tue	3.00	-0.01	3.63	3.76	0.02	92.20	150.04	320.15	470.83	593.58
37	25Jan55	15	Tue	3.00	-0.01	3.64	3.77	-0.01	92.20	150.04	320.24	454.41	639.38

To understand why one of the two parallel reservoirs (Cary) was reducing its outflow while the other (Bishop) was increasing its outflow, it is necessary to compare the Levels for both reservoirs. The Levels for Bishop and Cary have been tabulated next to each other to facilitate an easy comparison. The decision for Bishop to increase outflow was based on the fact that its flood pool was fuller at the beginning of period 12 (level 3.07 for period 11 compared to Cary's level of 3.05) . Therefore, Bishop had the priority to make use of the available space at Centerville. In period 14 both reservoirs reduced their releases to their respective minimum flows, which they maintained until period 34. The default operation would be to not release flow that would contribute to flooding downstream. However, recall that in this example, a priority was given to release minimum flows even though the releases might contribute to flooding (**J2** Record, field 4). In the last four columns, the space available for upstream reservoirs to fill with releases (Q Space) for Centerville, Zelma, Unionville, and Dry Town is shown. The negative values shown in these columns indicate both the timing and magnitude of flooding.

A detailed review of Table C.21 explains the operation of the Avon and Cary *tandem* reservoir sub-system. Of interest in this table is the operation of Avon in period 18, during which the outflow from Avon is reduced from 150.0 m^3/s to 58.62 m^3/s. Avon's Case for period 18 is 0.05, which indicates a *tandem* reservoir operation. In this example, Avon does not operate for a limiting channel capacity at a downstream control point; rather, it operates to balance levels with a downstream reservoir (Cary). At the end of period 17, Cary's level was 3.25 and Avon's level was 3.23. Therefore, Avon reduces its outflow in period 18 in order to match Cary's level in the previous period. Since Cary's level continued to rise, Avon reduced outflow to its minimum value at the next decision time (period 22).

The operation of the three *parallel* reservoirs (Bishop, Cary, and Donner) is shown in Table C.22. The operation of Donner shows that its release was reduced from 30.44 m^3/s to 3.35 m^3/s to decrease flooding at Dry Town (location 5) eight periods in the future (period 12 Case for Donner = 5.08). The flood reduction operation of Bishop and Cary was previously reviewed in Table C.20. However, they are presented in Table C.22 to illustrate that all three of these parallel reservoirs cut back their outflows to minimum flows by period 14 in order to reduce downstream flooding. By period 34, the downstream flows had receded and larger releases from the reservoirs were resumed in order to evacuate their flood control storage.

In summary, it may be said that the operation of the upper three reservoirs of the system (Avon, Bishop, and Cary) was based on reducing flows at Centerville (even though Avon did not directly operate for Centerville, its operation was impacted by Cary's operation for Centerville). The operation of the lowest reservoir in the system (Donner) was based on reducing flows at Dry Town.

Table C.22 User Designed Output: Operation of System Parallel Reservoirs (Example 3)

*USERS. 3 User Designed Output (Dates shown are for END-of-Period)

Summary by Period Flood= 1

Location No=				44.	22.	11.	44.	22.	11.	44.	22.	11.	5.
J8/JZ Codes=				44.100	22.100	11.100	44.130	22.130	11.130	44.120	22.120	11.120	5.040
				BISHOP DA	**CARY DAM**	**DONNER D**	BISHOP D	CARY DAM	DONNER DA	BISHOP DA	CARY DAM	**DONNER D**	**DRY TOWN**
Per	Date:	Hr	Day	**Outflow**	**Outflow**	**Outflow**	Level	Level	Level	Case	Case	**Case**	**Flow Reg**
1	21Jan55	3	Fri	148.50	100.02	22.77	3.00	3.00	3.00	0.03	0.01	0.03	333.14
2	21Jan55	6	Fri	148.50	100.02	24.95	3.00	3.00	3.00	0.03	0.01	0.03	335.83
3	21Jan55	9	Fri	148.50	100.02	24.95	3.00	3.00	3.00	-0.01	-0.01	-0.01	340.28
4	21Jan55	12	Fri	178.50	100.02	25.78	3.00	3.00	3.00	0.02	0.01	0.01	349.84
5	21Jan55	15	Fri	178.50	100.02	25.78	3.01	3.00	3.00	-0.01	-0.01	-0.01	366.21
6	21Jan55	18	Fri	208.50	100.02	26.95	3.02	3.00	3.00	0.02	0.01	0.01	378.16
7	21Jan55	21	Fri	208.50	100.02	26.95	3.02	3.01	3.00	-0.01	-0.01	-0.01	394.94
8	21Jan55	24	Fri	208.50	100.02	26.95	3.03	3.02	3.00	-0.01	-0.01	-0.01	414.89
9	22Jan55	3	Sat	208.50	100.02	26.95	3.04	3.03	3.01	-0.01	-0.01	-0.01	434.36
10	22Jan55	6	Sat	28.50	103.02	30.44	3.05	3.04	3.01	0.02	0.01	0.01	462.97
11	22Jan55	9	Sat	28.50	103.02	30.44	3.07	3.05	3.01	-0.01	-0.01	-0.01	494.47
12	22Jan55	12	Sat	58.50	69.19	**3.35**	3.10	3.07	3.02	0.02	20.03	**5.08**	510.04
13	22Jan55	15	Sat	58.50	69.19	3.35	3.13	3.09	3.03	-0.01	-0.01	-0.01	493.67
14	22Jan55	18	Sat	**20.00**	**2.20**	**1.10**	3.17	3.12	3.04	0.00	0.00	0.00	506.20
15	22Jan55	21	Sat	20.00	2.20	1.10	3.20	3.16	3.06	-0.01	-0.01	-0.01	544.21
16	22Jan55	24	Sat	20.00	2.20	1.10	3.24	3.20	3.07	-0.01	-0.01	-0.01	553.41
17	23Jan55	3	Sun	20.00	2.20	1.10	3.28	3.25	3.09	-0.01	-0.01	-0.01	525.64
18	23Jan55	6	Sun	20.00	2.20	1.10	3.31	3.30	3.11	0.00	0.00	0.00	541.06
19	23Jan55	9	Sun	20.00	2.20	1.10	3.34	3.35	3.13	-0.01	-0.01	-0.01	620.73
20	23Jan55	12	Sun	20.00	2.20	1.10	3.36	3.39	3.17	0.00	0.00	0.00	**722.53**
21	23Jan55	15	Sun	20.00	2.20	1.10	3.39	3.43	3.21	-0.01	-0.01	-0.01	861.12
22	23Jan55	18	Sun	20.00	2.20	1.10	3.41	3.46	3.25	0.00	0.00	0.00	981.38
23	23Jan55	21	Sun	20.00	2.20	1.10	3.44	3.49	3.29	-0.01	-0.01	-0.01	1036.43
24	23Jan55	24	Sun	20.00	2.20	1.10	3.46	3.52	3.32	-0.01	-0.01	-0.01	1009.01
25	24Jan55	3	Mon	20.00	2.20	1.10	3.48	3.55	3.35	-0.01	-0.01	-0.01	936.04
26	24Jan55	6	Mon	20.00	2.20	1.10	3.51	3.57	3.38	0.00	0.00	0.00	910.02
27	24Jan55	9	Mon	20.00	2.20	1.10	3.53	3.59	3.41	-0.01	-0.01	-0.01	921.49
28	24Jan55	12	Mon	20.00	2.20	1.10	3.55	3.62	3.44	0.00	0.00	0.00	923.46
29	24Jan55	15	Mon	20.00	2.20	1.10	3.57	3.64	3.46	-0.01	-0.01	-0.01	894.80
30	24Jan55	18	Mon	20.00	2.20	1.10	3.59	3.66	3.49	0.00	0.00	0.00	856.27
31	24Jan55	21	Mon	20.00	2.20	1.10	3.61	3.69	3.51	-0.01	-0.01	-0.01	821.89
32	24Jan55	24	Mon	20.00	2.20	1.10	3.62	3.71	3.53	-0.01	-0.01	-0.01	797.55
33	25Jan55	3	Tue	20.00	2.20	1.10	3.64	3.73	3.56	-0.01	-0.01	-0.01	787.01
34	25Jan55	6	Tue	**41.43**	**47.20**	**100.00**	3.66	3.74	3.57	20.02	0.02	0.01	762.79
35	25Jan55	9	Tue	41.43	47.20	100.00	3.67	3.75	3.58	-0.01	-0.01	-0.01	755.75
36	25Jan55	12	Tue	21.81	92.20	1.10	3.68	3.76	3.60	5.01	0.02	0.00	772.22
37	25Jan55	15	Tue	21.81	92.20	1.10	3.70	3.77	3.62	-0.01	-0.01	-0.01	812.56

Tabular output can be very useful in a detailed analysis of a simulation. However, for a complex reservoir system, a graphical review is also helpful. Therefore, use of the HEC-DSS graphics program DSPLAY can be most useful. Computed results can be written to an HEC-DSS file by using the **JZ** and **ZW** Records. HEC-5 simulation was complete. These graphical presentations are extremely helpful in illustrating the flood situation at Centerville. In Figure C.6 Centerville's channel capacity, regulated flow and the flow from upstream reservoirs are shown. From this plot it may be concluded that the reservoirs contributed only a minor portion of flow during the period of flooding at Centerville. From earlier review of Table C.20, we know that both reservoirs (Bishop and Gary) operating for Centerville only released their minimum flows during the time of flooding. In Figure C.7, Centerville's channel capacity, regulated flow and uncontrolled local flows are shown. This plot also leads to the conclusion that the uncontrolled runoff below Bishop and Cary is responsible for the excess flow at Centerville.

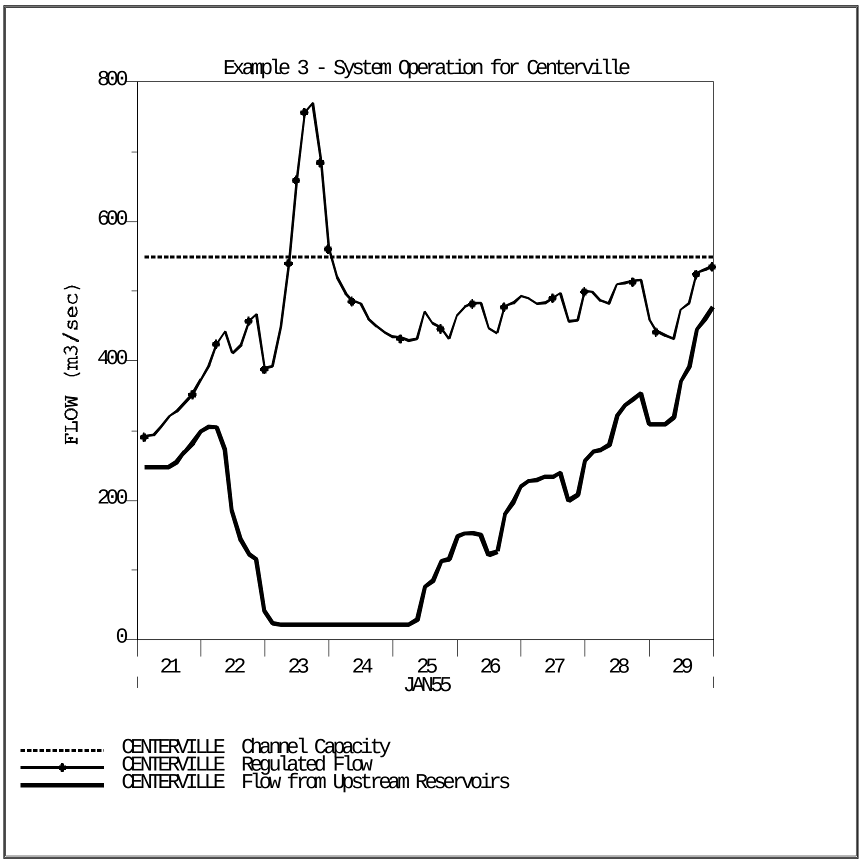

Figure C.6 Effect of Reservoir Releases on Centerville Regulated Flow (Example 3)

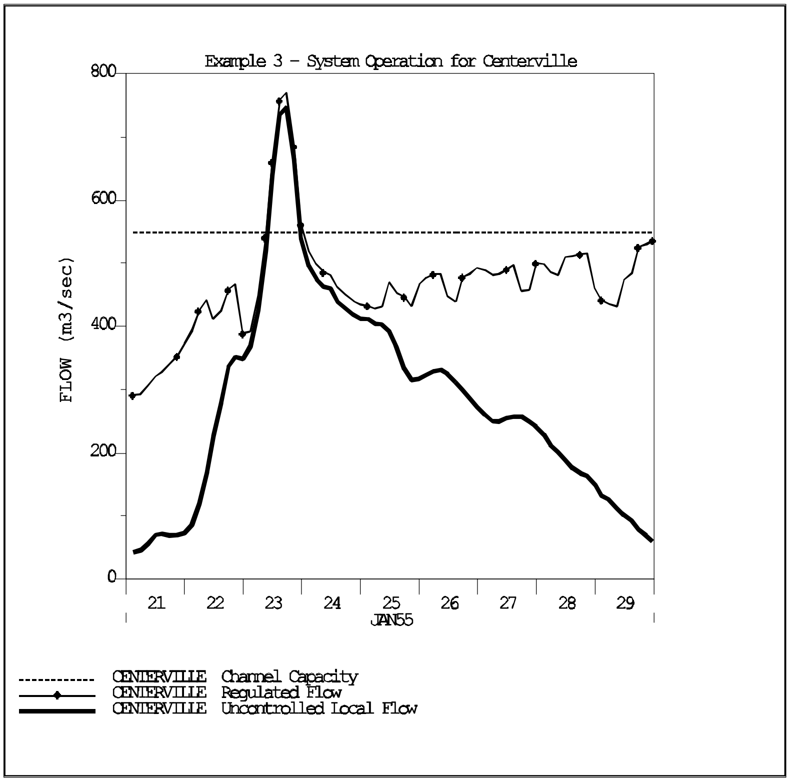

Figure C.7 Effect of Uncontrolled Local Flows on Centerville Regulated Flow (Example 3)